FOREST PRODUCTS RESEARCH 1950

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE FOREST PRODUCTS RESEARCH BOARD

WITH THE REPORT OF
THE DIRECTOR OF FOREST PRODUCTS RESEARCH

FOR THE YEAR
1950

LONDON: HIS MAJESTY'S STATIONERY OFFICE
1951

FOREST PRODUCTS RESEARCH BOARD

1950

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	Colonial Office ..	J. W. Vernon, Esq.
	Ministry of Supply ..	W. Hardy, Esq.; E. L. Hill, Esq.
	Ministry of Works ..	W. Abnett, Esq.

[1] Until 31st March, 1950.
[2] From 1st April, 1950.

Department of Scientific and Industrial Research,
Charles House, 5–11 Regent Street,
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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1950

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board, beg leave to submit our report for the year ending 31st December, 1950.

During the year no significant changes have occurred in the national timber situation which would cause any corresponding change in the emphasis or the orientation of the Laboratory's work. The restricted supply of softwoods and of certain of the traditionally utilized hardwoods continues, and so therefore does the necessity for the examination and assessment of all accessible timbers which might be used as substitutes. The testing of Colonial timbers is thus still the main preoccupation of the Laboratory's staff, apart from the still increasing advisory work, much of it on these new timbers, and its associated short-term investigations. Such time as remains from these heavy commitments has been devoted to fundamental and longer term work, and we must again record our opinion that this remainder is much too small a proportion of the total, important and desirable as the advisory contribution is to the timber-using industries.

We are pleased to record the good relations existing between the Laboratory and industry, public bodies and other departments, and to note that these relations are being continually broadened and improved. We would particularly commend to your Lordships' notice the close and effective co-operation with the Architect, the Ministry of Works and the contractors in the matter of the timbers for the rebuilding of the House of Commons. It provides an excellent example of the kind of useful yet unobtrusive service which the Laboratory is fitted to render.

Once more we would wish to record our thanks and indebtedness to the Economic Co-operation Administration in sponsoring an extended survey of an American industry—this time for making possible a visit by the Head of the Section of Wood Preservation to many representative preservation plants and to technical institutions in the United States. The knowledge gained on this tour is proving of very great value.

UTILIZATION OF COLONIAL TIMBERS

We have mentioned that the testing of these timbers still enjoys highest priority. During the year it has been possible not only to sustain the work on their assessment, but also to extend the survey of the using industries and to increase the number of visits to potential users. The dissemination of information on the production and uses of these timbers both as substitutes and as new materials in their own right still ranks in importance with the provision of the technical data themselves. At the production end, the training

of the Colonial utilization officers has now gone far, and it is hoped that before long each forest service will have at least one utilization officer who has been trained at this Laboratory.

HOME-GROWN TIMBERS

We expect to see in future years a considerable expansion of co-operative research with H.M. Forestry Commission. The approaching maturity of softwoods in some of the Commission's plantations in different parts of the country will provide an opportunity for the examination of different species from various localities. This should yield valuable data not only for the most efficient utilization of the present crop, but also for guidance in future planting and procedure. The work will be undertaken in collaboration with the Commission's recently established research station at Alice Holt.

BENDING OF TROPICAL TIMBERS

It is remarkable that, with few exceptions, none of all the tropical timbers so far examined possesses the good bending properties of the traditional temperate-zone ones, which are now in restricted supply. This has hitherto limited the use of the tropical species, which are in much better supply, for bending work in industry. The problem of bending these exotic timbers has now been satisfactorily solved by a process, recently evolved at the Laboratory, which enables these timbers to be bent to a curvature of much smaller radius than has hitherto been possible.

SHIPS AND BOATS

The experimental work on the use of timber in small marine craft is still increasing. The research on the durability of various plywood and glued assemblies has been amplified by studies on laminated beams immersed to their half length in sea water. Mycological work is also proceeding.

DRY ROT AND INSECT PESTS

The decay of woodwork in buildings and the infestation by insects of timber both in store and in structures still constitute a serious menace, the control of which lies largely in the education of the public in the recognition and treatment of damage. The success of a small exhibition shown last year led to the sending on tour of a much more comprehensive one to some towns. Reports on the numbers of visitors, the demands for leaflets and the sales of literature show that the attendance at the exhibition has been most gratifying. Its tour will be continued during 1951.

E. J. SALISBURY,
Chairman

March, 1951.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1950

INTRODUCTION

During the year 1950 the work of the Laboratory has progressed steadily along the same general lines as in previous years. There has been no effective difference in the general national situation in respect of timber, which largely determines the trend of day-to-day work, and to some extent also, although more distantly, the orientation of the fundamental work.

There is no falling off in the number of incoming species of Colonial origin, particularly from West Africa, which are potentially of use either for replacing those from hard-currency areas or as new timbers in their own right. The testing and evaluation of these new woods therefore remains the largest project engaging all the technical sections of the Laboratory, and together with the still increasing volume of advisory work, continues to absorb much of the available staff time.

In spite of preoccupation with these tropical species during recent years, work upon home-grown timbers has never been overlooked, and there has been a constant, though necessarily restricted, co-operation with the Forestry Commission on research projects of common interest. Two factors, however, have now made it possible to envisage a much wider and closer-knit programme of work with the Commission—the coming into full operation of their research establishment at Alice Holt in Surrey and the approaching maturity of certain of their plantations. The time is now at hand when information on the qualities and properties of their timber will be important both as regards the fate of the timber itself and as providing guidance for future sylvicultural operations. Arrangements for the expansion of the joint programme are now being made.

The co-operation with industry, public bodies and with other government departments, has been wide and satisfactory, and continues to increase. Reference to them has been made in the appropriate places in this report. The customary service has also been provided for committees of the British Standards Insitution and for work on Codes of Practice, etc.

One instance of close and pleasant co-operation extending over some years is that occasioned by the work in rebuilding of the House of Commons. A note on the Laboratory's part will be found on page 6 of this Report.

GENERAL

STAFF

No changes have taken place during the year in the senior grades. There has been, however, a significant exodus of those younger people who, engaged as scientific assistants during the last four or five years, have by now taken their Intermediate B.Sc., have become Assistant Experimental Officers, and desire to go forward for a degree. With the exception of the B.Sc. degree in

Physics (which can just be managed by very arduous travelling to night classes in London) a degree course cannot be attended from Princes Risborough, and a transfer is therefore requested by those who wish to graduate. There is at the present time no way out of this difficulty which results in a regular loss of trained and ambitious juniors.

BUILDINGS AND EQUIPMENT

Three of the four new premises—the Structures Laboratory, the Woodworking Laboratory, and the extension to the Woodworking Machine Shop—are nearing completion and should be ready for full occupation early in 1951. The plans for the completion of the Seasoning Section are ready and building is expected to begin at any time. Much of the experimental machinery for the Woodworking Laboratory has been delivered and is already being installed.

TOURS

In the spring of the year the Head of the Section of Wood Preservation spent over three months in the United States and Canada studying American wood-preserving practice. The visit, which brought much valuable information, was made under the auspices of the Economic Co-operation Administration to whom, as well as to those members of the British Commonwealth Scientific Office who ensured the smooth running of the very full programme, grateful thanks are due. Some technical observations on the tour will be found on page 37.

Three senior members of staff attended the VII International Botanical Congress, held in Stockholm in July. They used the opportunity of making useful technical visits in the Scandinavian countries.

The Head of External Relations Section attended at Geneva as ' rapporteur ' to a working party of experts set up by the Economic Commission for Europe to consider improved methods of timber utilization.

ADVISORY PANELS

The three informal advisory panels—the Adhesive Makers' Panel, the Radio Frequency Panel and the Plywood Research Panel—have held their usual meetings during the year. The Adhesive Makers' Panel has now been in existence for five years, and at a recent meeting the opportunity was taken of examining the efficacy of its manner of working over the period. There is no doubt that where it is desired to bring together representatives of competitive interests for the discussion of common problems the informal panel, convened impartially and conducting its business without formal minutes, is a very useful instrument.

PUBLICATIONS AND RECORDS

New publications issued through the Stationery Office during the year were the Annual Reports for 1939–1947 and 1948. Bulletin No. 24 " The Protection of Buildings and Timber against Termites ", prepared during the year, will be published early in 1951. In addition to these, a revised edition was issued of Special Report No. 6 " Swelling Stresses in Gels ", and the " Handbook of Empire Timbers " was again reprinted with minor amendments. New leaflets include No. 46 " Marine Borers and Methods of Preserving Timber against their Attack " and two Supplements to No. 44 " The Seasoning of Exotic

Timbers ". Eighteen papers were also published in the scientific and technical press (see Appendix II) and twenty-five reports dealing mostly with plywood and with the properties of various exotic timbers were prepared for limited distribution.

A manual on kiln-seasoning for the use of kiln operators is in course of preparation.

THE ADVISORY SERVICE

The Reports of the last few years have indicated how the increasing volume of industrial and general advisory work, with its associated short-term research, has occupied a rising proportion of available staff time. In former Reports, also, the influence of this welcome but serious burden upon the general programme has been fully discussed.

Since the advisory work is now one of the chief activities of the Laboratory and the clearest expression of its service to industry and to the public, a short survey of a typical year's work is not without interest.

An enquiry is dealt with in one of two ways. If it is of a routine nature it is met by sending out a standard leaflet, and this type of reply suffices for a large number of queries on dry rot, wood-worm, kiln schedules and the like. It is not feasible to give accurate figures for the enquiries dealt with by leaflet or other form of publication, because more than one may be sent to a single enquirer. During the year, however, 44,800 leaflets were distributed.

At this Laboratory the non-routine enquiry is routed directly to the appropriate specialist Section. This ensures a prompt reply, combined with the maximum economy of effort. Experience has shown that in an establishment of a dozen highly specialized sections serving a very diverse industry, this direct method cannot be satisfactorily replaced by any form of centralized information bureau.

In 1950 replies by letter alone amounted to 5,934, and in addition much time was spent by senior officers on giving information directly to visitors or by telephone.

The question of payment for investigations is decided by their individual interest to the Laboratory. If, however desirable it may be to undertake an investigation, the amount of work involved is not altogether warranted by its research interest, then an appropriate charge is made.

The range of subjects dealt with in the advisory work is extraordinarily varied. Within certain specialist sections the variation must of course lie within a much narrower ambit than that of others, while with some the mass of routine enquiries is less often relieved by those of exceptional interest. An analysis of the enquiries of one Section—Chemistry—which has a very wide range of subjects, will, however, give some idea not only of the varying day-to-day work which is done but also of the remarkably broad experience in timber technology which must be brought to it.

In the Chemistry Section, 341 enquiries were dealt with in the year under review. Of these, 54 were answered by telephone, 260 by letter or report, and 25 in the course of either consultations at the Laboratory or visits to industrial firms. Although the bulk of the answers to these enquiries was based on existing knowledge, laboratory work of up to 40 man-hours in some instances was required to provide answers to over 10 per cent of the total enquiries

received. In addition, nine enquiries resulted in laboratory work or short-term researches each extending over periods of weeks. In one the results were submitted for publication.

The subject matter of the enquiries exhibited the usual diversity and is classified under fifteen separate headings as follows :

	No. of Enquiries
Wood components (including exudates and extractives) ..	33
Chemical products derived from wood	13
Bleaching and finishing of wood and wood products ..	13
Natural defects (cause and treatment)	21
Stains and degradations by chemical agencies (cause and treatment)	25
Deposits of extraneous origin found in wood	13
Resistance of specific woods towards chemicals	7
Wood taint in foodstuffs, including beverages	7
Chemical utilization of wood waste	6
Wood pulp and fibreboard	20
Wood/inorganic cement composites	4
Wood/glue composites (including identification of glues) ..	9
Wood/metal composites (including metallic corrosion caused by wood and its prevention)	30
Selection and treatment of woods for specific purposes where chemical considerations are involved	105
Miscellaneous	35
Total	341

In the largest group of 105 enquiries, specific uses fell under 27 separate sub-headings as follows :

Battery separators, bench tops (laboratory), bobbins, cable drums, cooling towers, decking (ships'), draining boards, dyeing poles, filter press frames, fish trays, fire lighters, floors (chemical-resistant), food-chopping boards, grids for gas-scrubbing towers, joists for hop kilns, lids for boiling pans, etc., linings for pickling tanks, dye and glue vats, moulding sands, mounting blocks for steeplejacks' ladders, packing cases for foodstuffs, metal goods, etc., paddles and stirrers, pipelines for corrosive chemicals, printing blocks, refrigerator cars, sinks, sifting frames, slide rules, tanks and vats, and tanning drums.

Other items of interest in the Laboratory's advisory work are dealt with in the reports of the various sections.

THE REBUILDING OF THE HOUSE OF COMMONS. THE LABORATORY'S PART

It is now some five years since the Laboratory was first consulted in regard to the selection and preparation of timber for installation in the newly-restored House of Commons, and since then a considerable amount of time and work has been devoted to the project.

As early as March 1945 the advice of the Laboratory was sought by Sir

Giles Gilbert Scott, the architect of the House, as to suitable Australian woods for the making of the Speaker's Chair, and in August of that year a representative of the Laboratory accompanied Sir Giles and Sir Charles Mole to inspect parcels of English oak likely to prove suitable for the rebuilding of the main chamber. Further visits and conferences were arranged as the project progressed, and specifications were drawn up relating to the method and degree of seasoning required for such timbers as were to be used. From the start, the Architect had insisted that all the woods from whatever source should harmonize in colour and, accordingly, several inspections were made of the collection of wood samples in the Wood Structure Section of the Laboratory to enable him to decide which of the woods offered by the various Colonies would be suitable.

Sir Giles also consulted the Laboratory on the possibility of darkening the oak from its original colour to a shade of which he had a sample. After investigation, a simple treatment was found to give the result he desired.

By this time, the plans for the rebuilding were well advanced and the Laboratory was again consulted on the seasoning of the oak, which included some very heavy sections for the roof.

The quantities of timber involved were very considerable, and the time available was such that a thorough air-drying or in many instances even a partial air-drying of the newly felled material was ruled out and artificial or kiln-seasoning methods had of necessity to be employed. Only by the use of modern seasoning kilns would it, in fact, have been possible to dry the material to the required moisture content in the time set, and this only after some re-design had made possible a reduction in the thickness of many of the heavier timbers of the original specification.

The Laboratory readily agreed to co-operate closely in an advisory capacity with the firm responsible for kiln-drying the timber. While this involved the commitment that members of the Seasoning Section should visit the plant from time to time in order to offer general advice as to the kilning procedure adopted and to check the final condition of the timber, yet it was felt that, apart from the importance of the work, this service would yield to the Laboratory the valuable experience of close and continuous contact with commercial operation on a large scale which, owing to the unfailing helpfulness of the contractors, indeed it did.

Comparatively thin and partly air-dried material was at first dealt with and little trouble was experienced in seasoning this satisfactorily. By the end of 1947, however, some of the thicker and wetter material was in the kilns, and drying times and difficulties increased to a greater extent than was expected. In one of the larger kilns, for example, variations existed in the air conditions from end to end which were of little consequence when the thinner material was being dried, but the effect of these differences became greatly magnified in dealing with the very slow-drying thicker material, and at this stage it became necessary to carry out tests in this kiln and to suggest certain alterations of the internal heating equipment, in order to produce improved uniformity in the drying rates throughout the drying chamber. Apart from the general uniformity of drying, the internal distribution of moisture and stress within the oak was deemed important because of the depth to which it was to be moulded or carved. This lengthened the period of drying and conditioning needed,

particularly with the thicker oak, and to give some idea of the times involved it may be stated, for instance, that a load of 4½-inch material was in the kiln for a period of 9½ months before the degree of uniformity considered to be acceptable had been obtained. Even so, and despite prolonged periods of conditioning, the moisture content in the core of the quartered material was in some instances higher than was originally intended.

These drying times, which were appreciably in excess of the original estimate, taxed the kilning capacity to the utmost and, in fact, it became necessary to have a few loads dried by kilning firms elsewhere and also in two of the large kiln units at the Laboratory. At this stage visits to one or other of the firms concerned were made by members of the Seasoning Section about once a week, and the volume of moisture-testing and advisory work added considerably to the normal routine and research work of the Section.

In view of the care with which the timber was being seasoned to a fixed content, it was obviously important that it should not be exposed to adverse moisture conditions during manufacture and storage pending its installation or, of course, when finally erected in the House. Steps were therefore taken to observe the drying-out of the new fabric of the building and it was further arranged at the Laboratory's request for a periodic check to be made on the moisture conditions in those stores and workshops where the timber was to be worked or carved, as well as in the House itself. This again added to the work of the staff, but again yielded valuable additional data on commercial operational conditions, as well as a very ready and pleasant co-operation with the firms themselves.

The stability and appearance of the timber in the new House bears witness to the careful and successful attention to detail displayed by all those concerned in its preparation.

In the meantime, the Laboratory, at the request of the Architect, had also undertaken the kiln-drying of gift parcels of fine timbers which had been presented by the Colonies for the furniture of the new House. Altogether twelve separate parcels were received for this purpose and, while none of them was large in total volume, they all contained a wide variety of sizes. This variation in size, together with the fact that the largest pieces were in general appreciably wetter when received than were the small ones, made the task of reducing the timber to a uniformly dry condition much more difficult than it would otherwise have been. Before the kiln-drying could begin, the timber supplied had to be measured and care taken to ensure that in selecting representative samples for test purposes, no pieces were destroyed which would be required by the cabinet makers. In a few instances, the timber arrived in very large sizes bearing no relation to those in which it was ultimately to be used, and this had to be converted to smaller dimensions in order to make kiln-drying at all practicable.

Fortunately, eight of the timbers had moisture contents no higher than about 20 per cent on arrival, and in spite of the variety of sizes it was possible to bring them to a suitable condition for use in relatively short periods, ranging from two to four weeks. These timbers were white seraya (from North Borneo), iroko (from Nigeria), mansonia (from the Gold Coast), mvule (from Uganda and from Tanganyika), 'African walnut' (from Sierra Leone), birch (from Newfoundland) and mayflower (from British Honduras). The remaining parcels

all contained some pieces which were virtually green, and only one can be said to have dried readily. This was a small parcel of iroko, the gift of St. Helena, which consisted of planks up to $2\frac{5}{8}$ in. thickness and which was dried with remarkably little degrade in three weeks. The puriri given by New Zealand for the Despatch Boxes proved to be refractory but, fortunately, it could be cut down to boards only $1\frac{1}{8}$ in. thick before seasoning. Even so, these boards were extremely reluctant to yield moisture from their centres and the kiln treatment lasted for the exceptionally long period of 4 months. By way of comparison, it may be mentioned that similar boards of English oak, normally regarded as difficult wood to season, could have been dried in four to five weeks. In spite of the fact that a very mild treatment was given, some of the puriri boards warped appreciably, and in others some collapse occurred, but their final state was greatly improved by the application of a reconditioning treatment at the end of the drying run. The remaining parcel, presented by Kenya, was of loliondo and was troublesome in that a comparatively small number of pieces, 2 and $3\frac{1}{2}$ in. thick, were very much greener than the rest. In thick sizes, loliondo is another species which parts very slowly with its moisture and, although the parcel was dried very carefully over a period lasting nearly four months, some honeycombing developed in thick pieces.

Despite the difficulties encountered, however, adequate supplies of seasoned timber were made available for each purpose, and the new House of Commons was finished and opened on the date set. In the carrying out of the work outlined above, the Laboratory was able not only to be of some assistance, but also to obtain most useful data and information that would not otherwise have been easy to acquire on the seasoning of exceptionally thick material from several refractory species.

PROGRAMME OF RESEARCH

WOOD STRUCTURE

For another year the main work of the Wood Structure Section has been along severely practical lines directed towards the efficient utilization of the country's timber supplies. Following the changes which have taken place in the timber situation, particularly in the last few years, an increasing proportion of the staff's activities has been in the field of economic botany rather than that of wood structure. Apart from the work on the physiology of heartwood formation, research in wood structure has in fact been practically restricted to identification studies.

In acting as a clearing house for information on utilization questions and in particular on the choice of timbers for various purposes, it is clearly necessary to know what species of timber are available and roughly in what quantities. The pattern of hardwood imports is at present so kaleidoscopic that this is now a very complex matter, and in order to maintain a reasonably accurate picture of the situation it is necessary to carry on an analysis of the monthly statements of hardwood imports supplied by the Board of Trade. It is noteworthy that nearly every month sees a few more new names on the list of imported hardwoods—over fifty new names appeared in 1949 and another thirty in the first nine months of 1950. Some of these prove to be unfamiliar names for established species but a considerable proportion is found to refer to practically unknown timbers, and special studies must be undertaken to identify the species

concerned and make at least a provisional assessment of their properties and potential value to industry.

Sooner or later each of these " new " timbers will be the subject of an enquiry, and it is thus desirable that the Laboratory's experts should be able to recognize samples of all the commercial timbers ; moreover, enquirers commonly expect to be supplied with basic technical information on the timber in question and advice on how best to use or otherwise dispose of the parcel in their possession. It is therefore necessary for the identification studies to keep pace with changes in the supply position.

Finally, any timber entering the market for the first time in appreciable quantities is a potential substitute for other timbers in short supply and must therefore be taken into account when alternatives are being considered for one purpose or another.

Identification Studies

Good progress has been made with the important albeit unspectacular work on specific timbers the study of which provides the basis for routine work on identification. The main lines of this work are determined by the ever-growing list of imported hardwoods. It is both scientifically and economically more satisfactory to study timbers in natural groups than as isolated units and so far as possible studies of individual commercial timbers are extended to cover related species of economic or scientific interest. The exploitation of a number of closely related, though not identical species of *Shorea* in different parts of South East Asia and their export under different commercial names provide a case in point. It involves the co-ordination of published information, usually based on restricted regional observations, together with a survey of the available specimens, some of them authentic and reliably named, others representing the commercial timber rather than any definite botanical species. The *Shorea* group of timbers was the subject of Forest Products Research Record No. 12 (Seraya, Meranti and Lauan) published in 1936. It is intended to bring this up-to-date and issue a revised edition. The development of timber exports from Malaya, Siam, North Borneo, Sarawak and Indonesia has necessitated similar studies of many other timbers of this region.

Keys to Hardwoods

Continual additions to the number of hardwoods in current use has entailed frequent extensions to the card keys for their identification. For some years past it has been the intention to publish the lens key to hardwoods in a form suitable for use by students and others, but this has been repeatedly deferred because of the difficulty of keeping it up-to-date. The latest revision of the key is, however, now practically ready for the press and it is hoped that it will be published in 1951.

Experimental Work in Plant Physiology

Physiology of Heartwood Formation. It is believed that the cessation of the flow of sap is an important factor in initiating the series of chemical and anatomical changes which result in the conversion of sapwood to heartwood. It was mentioned in last year's Report that an experimental girdling technique had been worked out for interrupting the flow of sap without, it is thought, seriously interfering with the vitality and normal physiological activities of the

tree. Observations made so far show that some but not all of the changes which occur in normal heartwood formation can be induced in this way, although it may well be that other factors than those brought into play by the interruption of sap flow are involved in the normal process. The experiments aim at elucidating the physiological processes involved in heartwood formation. It is, however, too early to say whether their results will lead to the discovery of a practical method of accelerating the change or of increasing the proportion of heartwood in commercial timber.

Starch Depletion in Timber. No special studies of starch depletion in felled timber have been carried out during the year. Those changes in starch content which accompany the conversion of sapwood to heartwood in the growing tree are dealt with in the experiments on Heartwood Formation.

Advisory Work in Wood Structure

During the year the number of outside enquiries involving a written reply amounted to 753. A large proportion of these entailed the identification of commercial samples but in addition a wide range of advice and information has been furnished on the quality or condition of the timbers, their technical properties and suitability for particular purposes.

For some time past the quantity of softwood available has been insufficient to meet the demands of industry and it has become increasingly general to substitute hardwood for softwood wherever practicable. Many enquiries have been concerned with the problem of selecting from the large number of hardwoods now on the market those which are most likely to be suitable for particular purposes. The full and efficient use of the existing hardwood supplies is hindered by lack of working knowledge of the many different kinds available, especially in those branches of industry which are traditionally dependent on softwood. In accordance with the official policy of substituting hardwood for softwood in building work the hardwood position has been reviewed and the relevant section of the Ministry of Works Economy Memorandum on the Use of Timber in Building Work has been completely revised. The list of timbers has been extended to include practically all general-purpose hardwoods imported in commercial quantities in 1949–50 and likely to be offered to builders, and notes have been prepared on the more important characteristics of the timbers and their suitability for building work generally. Much of the information provided is applicable to a wider field of operations than ordinary building work and will be found useful for reference in dealing with utilization questions generally.

The enquiries themselves have shown the usual diversity. Among the subjects upon which advice was sought during the last two months of 1950 were the following :

An importer asked for information on a number of timbers offered for export from South East Asia; a paper manufacturer was supplied with anatomical data on timbers under consideration for paper pulp; a yacht-builder asked for information on certain West African timbers offered in place of teak; a plywood importer submitted samples of alder plywood for advice on the nature of its discoloration; a technical college asked for information on timbers used in the printing trade; joinery manufacturers asked for advice on hardwoods suitable as substitutes for joinery-trade softwood; an importer submitted a

sample of an unfamiliar timber included in a consignment of Malayan light hardwoods; examination of a sample of oak suspected of being decayed showed that the brittle nature of the wood was due to the abnormal growth of the tree; an importer queried the identity of a sample included in a shipment of African walnut—it proved to be of an entirely different species; a private individual submitted for identification and comment a sample of timber supplied under the misleading name of shorea mahogany; a shipper enquired about the prospects of an unknown Borneo timber on the United Kingdom market; a furniture manufacturer enquired about alleged ill effects of certain hardwoods on operatives; a builder asked for advice on the use of certain Malayan hardwoods for glasshouse construction.

PHYSICS

Wood-water Relationships

Using a McBain quartz spring balance in a vacuum apparatus, further measurements have been made of the relative humidity-moisture content isothermals of Sitka spruce. The results are plotted in Figs. 1 and 2, in which

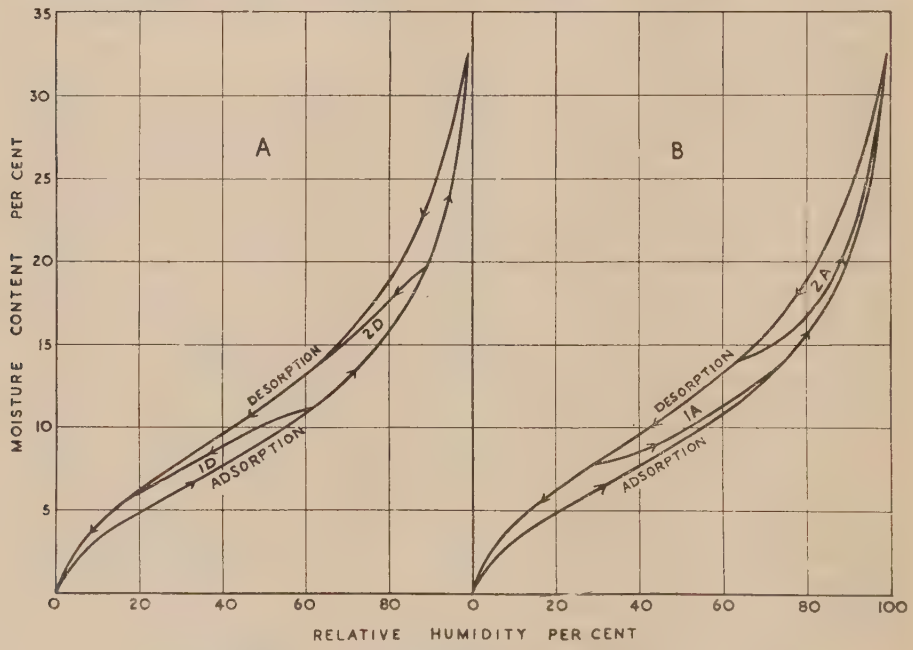


FIG. 1. SITKA SPRUCE ISOTHERMAL

the curves labelled " Adsorption " and " Desorption " correspond to changes in moisture content by stages from dryness to 32·5 per cent and back again. These curves appear to be completely stable and reproducible on repetition of the cycle of moisture content. The effect of putting the wood through smaller moisture content cycles has also been studied. Thus the curve 1D (Fig. 1A) was obtained by allowing the wood to adsorb water from dryness to 11·2 per cent moisture content, at which point desorption conditions were imposed. Observations of humidity and moisture content were made as the wood dried out by stages, sufficient time being allowed at each stage for equilibrium to

become established. The moisture content was then raised to 19·7 per cent and observations made along curve 2D (Fig. 1A). Drying was continued down to 7·9 per cent moisture content, after which the adsorption curve 1A (Fig. 1B) was obtained. Finally the wood was taken up to 32·5 per cent moisture content, down to 14·1 per cent moisture content, and along the adsorption branch 2A (Fig. 1B). This process of taking materials through incomplete hysteresis loops has recently become known as " scanning " and has been the subject of some theoretical discussion with regard to its possible use for indicating the way in which water is held by hygroscopic materials. This aspect of the interpretation of the results is, however, not yet settled, and a more immediate objective is the empirical comparison of the scanning behaviour of wood with that of other materials, of which cotton wool, silica gel and ferric oxide gel have been studied elsewhere. One practical conclusion which follows from the results is that it appears possible, by putting the wood through a suitable intermediate humidity cycle, to obtain an equilibrium point anywhere within the normal hysteresis loop. When samples are being conditioned, one of these intermediate equilibrium states may result if the final and initial moisture contents do not differ greatly. For accurate work it may therefore be necessary to put the wood through a preliminary conditioning treatment to ensure that the final state really corresponds to a point on the main adsorption or desorption curve. This point was made some years ago[1] as a result of some work on cotton, but its applicability to wood has not perhaps been sufficiently emphasized.

Diffusion of Water Vapour through Wood

The diffusion of water vapour into wood is analogous to the conduction of heat, and the equations governing the two processes are similar. In fact, if temperature be replaced by moisture content, and heat diffusivity by the diffusion coefficient for water vapour, the solution of any problem in heat conduction can be directly applied to the corresponding problem in the diffusion of water vapour. One relatively simple example occurs when a sheet of material at one temperature is taken to an environment at a different temperature. The temperature at any point within the sheet can then be calculated as a function of time in terms of the thermal diffusivity and the dimensions of the sheet; alternatively if the temperature is measured as a function of time the thermal diffusivity can be calculated. The corresponding problem in moisture uptake occurs when a piece of wood, conditioned to equilibrium at one humidity, is moved to an atmosphere of different humidity. The rate of uptake of moisture is measured, and the diffusion coefficient calculated from the results. This method has recently been used elsewhere to measure the diffusion coefficient of chloroform in polystyrene[2], and some experiments have been started at this Laboratory on wood. The measurements are complicated by the fact that the diffusion coefficient is not constant, but depends on the moisture content, and in an attempt to allow for this dependence, the experiments are being carried out in stages over fairly small humidity ranges. The specimens measure 4 × 4 in. and are of three thicknesses: $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$ in. They were dried to constant weight over phosphorus pentoxide, exposed to an atmosphere of 30

[1] URQUHART, A. R., and ECKERSELL, N. Moisture Relations of Cotton. A Study of Hysteresis. *J. Text. Inst.*, 1930, **21**, T499.

[2] CRANK, J., and PARK, G. S. Diffusion Coefficients for Chloroform in Polystyrene. *Trans. Farad. Soc.*, 1949, **145**, 240.

per cent relative humidity, and the rate of uptake of moisture determined. The diffusion coefficients calculated from the results of these experiments were found to depend on the thickness of the specimen, and it was suspected that diffusion of moisture through the edges and along the grain was responsible. The edges were therefore coated with moisture-proof paint, and the specimens exposed at 60 per cent relative humidity. To a first approximation the calculated diffusion coefficients were independent of thickness, thus lending support to the suggestion that edge diffusion caused the anomalous results of the first experiment. After attaining equilibrium at 60 per cent relative humidity, the specimens were exposed at 90 per cent relative humidity. The calculated diffusion coefficients were larger than the previous ones (i.e. the diffusion coefficient increases with increasing moisture content), and were again independent of thickness. The specimens are now being taken through the desorption cycle and the results will be analysed when the cycle is complete.

An alternative method of measuring the diffusion through wood is provided by the use of the Perspex vessels mentioned in previous reports. Attention has so far been confined exclusively to one relative humidity gradient across the sample (100 per cent) and mainly to one temperature (25°C.), and the rates of diffusion through seven species in the radial and tangential directions have been measured under these conditions. Beech and oak have been examined in more detail, and the diffusion rates at 10^{-2} mm. air pressure as well as at atmospheric pressure have been measured. The effect of temperature on rate of diffusion has also been investigated from 20° to 40°C., and on beech the effect of varying the thickness from $\frac{1}{16}$ to $1\frac{1}{2}$ in. at 25°C. has been measured. The results of these experiments are being tabulated and compared, and it is hoped shortly to incorporate them in a preliminary report.

Dielectric Properties of Wood

Measurements have been made of the dielectric constant and power factor of discs from 12 species of wood, conditioned to relative humidities of 30, 60 and 90 per cent. The discs were cut so that the properties could be measured in the three principal directions of the grain. The results show that both dielectric constant and power factor are greater—in some species considerably greater—in the longitudinal than in the transverse directions. There is little difference between the measured values in the radial and tangential directions, but the radial values are usually slightly higher than the tangential ones. The dielectric constant in all three directions falls with increasing frequency over the whole range examined (2 kc/s to 40 Mc/s). The curve of power factor against frequency, on the other hand, shows a minimum at a frequency which rises as the moisture content increases.

The dielectric constant behaves more regularly than does the power factor. At a given frequency and moisture content, the dielectric constant is proportional to density for all three grain directions. This result is interesting, but is as yet unexplained. If the gross wood is regarded as a mixture of wood-water aggregate and air, it is possible to calculate the dependence of dielectric constant on density for various assumed dispositions of the two in the gross wood. For example, a random arrangement of irregularly shaped particles of aggregate in air will give one curve, an assemblage consisting of alternate layers of aggregate and air arranged perpendicular to the electric field a second, and so on. The only arrangement which gives an overall dielectric constant pro-

portional to density consists in alternate layers of the two components disposed parallel to the field, but it has not yet been possible to suggest an arrangement such that this condition could be fulfilled simultaneously in the three principal directions.

There is little or no correlation between density and power factor, and it appears that when power factor is plotted against moisture content, the curve is divided into three distinct regions. As the moisture content is increased from zero to about 8 per cent the power factor increases; between about 8 and 14 per cent moisture content it remains steady or even decreases, and above 14 per cent moisture content it increases again. This behaviour is being examined on a further series of discs of Scots pine for which measurements will be made at a greater number of moisture contents than is possible on the main specimens.

The conductivity of the wood is proportional to the product of frequency, dielectric constant and power factor. The irregular behaviour of power factor is reflected in similar, though less marked irregularities in the conductivity. The longitudinal conductivity is, of course, greater than the transverse conductivities, and it is found that in all three directions at the lower humidities the logarithm of the conductivity is proportional to the logarithm of the frequency over a certain frequency range, which becomes smaller as the moisture content increases. Thus, on the specimens conditioned to 30 per cent relative humidity, the proportionality holds from about 50 kc/s up to 40 Mc/s, whereas on the samples conditioned to 60 per cent relative humidity, it holds from about 500 kc/s up to 40 Mc/s. On the specimens conditioned to 90 per cent relative humidity, the straight line portion of the curves practically vanishes, and the overall change of conductivity with frequency is much less than at lower humidities. This confirms earlier work on very wet wood, which indicated that under these conditions there was little or no significant change of conductivity with frequency.

Elastic Properties of Wood

In continuation of experiments carried out some years ago on the frequency of vibration and the central deflection under load of plywood plates, work has been started on the behaviour of plywood when subjected to pure bending and shear stresses. Particular attention is being paid to plywood cut so that the directions in which the stresses are applied lie at various angles to the face grain. This work offers possibilities of verifying the accuracy with which elastic theory can be applied to plywood, and also of measuring the elastic constants, particularly the Poisson's ratios, which are difficult to deal with by other methods. The first experiments, carried out on afara three-ply, are promising and the work is continuing.

Tests have also been made of a new method of measuring the modulus of elasticity of wood. In this method, the specimen is clamped in a vertical plane and carries a metal platform at its free end. Two compound pendulums swing from the platform in such a way that energy is transferred from one to the other through the specimen. This results in the amplitude of one dying away, while the other builds up; the amplitude of the first then builds up while the second dies away, and so on. The modulus is calculated from the frequency of the beats, and from certain other constants of the system. From preliminary measurements, however, it appears that the method is not only more

involved, but also less accurate than other methods and work on it has been abandoned.

Effect of Temperature on Shear Moduli of Beech

Tests carried out in Australia have indicated that temperature has a considerable effect on the mechanical properties of wood. This conclusion was arrived at by carrying out destructive tests on the wood, and is therefore uncertain to some extent owing to the variation in properties between one piece of wood and another. In order to confirm the effect of temperature, non-destructive tests have been made on a number of specimens subjected to changes of temperature at constant relative humidity. The tests so far completed have been made on the shear moduli of beech; strips of this timber measuring approximately 5 in. × 1 in. × 0·1 in. were cut in the correct directions for measuring the shear moduli in the three principal planes, the radial-tangential (RT), the tangential-longitudinal (TL) and the radial-longitudinal (RL). The strips were clamped at one end with their lengths vertical inside the humidity and temperature chamber briefly described in last year's Report. Inertia bars were fixed to the lower, free ends of the strips, and by means of an electromagnetic device, the inertia bars could be set into torsional vibration by operating a switch outside the oven. The period of the torsional vibrations was measured with a stop watch, and its variation with changes in temperature and humidity inside the oven was studied. The shear modulus (G) was then calculated from the period of vibration and the dimensions of the specimens.

The following scheme indicates the treatment to which the specimens were subjected. In each run the humidity was kept constant at the indicated figure, and the temperature changed from roughly 40°C. to 95°C. and back to 40°C. again.

Relative Humidity per cent	*Temperature Cycle °C.*	*Specimens*
30	40–100–40	1, 2, 3, 4 (All G_{RT})
30	40–100–40	
50	35– 95–40	
75	25– 90–30	
75	35– 95–30	1, 3(G_{RT}), 2A(G_L), 4A(G_{RL})
90	35– 95–30	
50	35– 95–40	
50	35– 95–40	
30	40– 90–45	

It will be seen that two of the strips (1 and 3) were taken through the complete cycle of treatment, whereas strips 2, 4, 2A and 4A were not. On strips 1 and 3, the observations taken as the humidity was increased agreed well with those taken as the humidity was decreased, and the shear moduli found at the end of the experiment did not differ significantly from those found at the beginning. Thus, as far as transverse rigidity modulus is concerned, there is no permanent effect of the rather prolonged exposures to high temperatures involved in the treatment. At any given humidity, the temperature was

altered in steps of about 10°, and it was found that after this alteration in temperature, the strips needed approximately 2 days before the readings became steady. It was also found in some examples that even when this period was allowed between readings, the observations taken in the initial heating cycle at a given humidity did not agree with those taken during the first cooling cycle, but that subsequent heating and cooling cycles gave results in complete agreement with the first cooling cycle. The results of these concordant observations are plotted in Fig. 2 for strips 1(G_{RT}), 2A(G_{TL}) and 4A(G_{RL}).

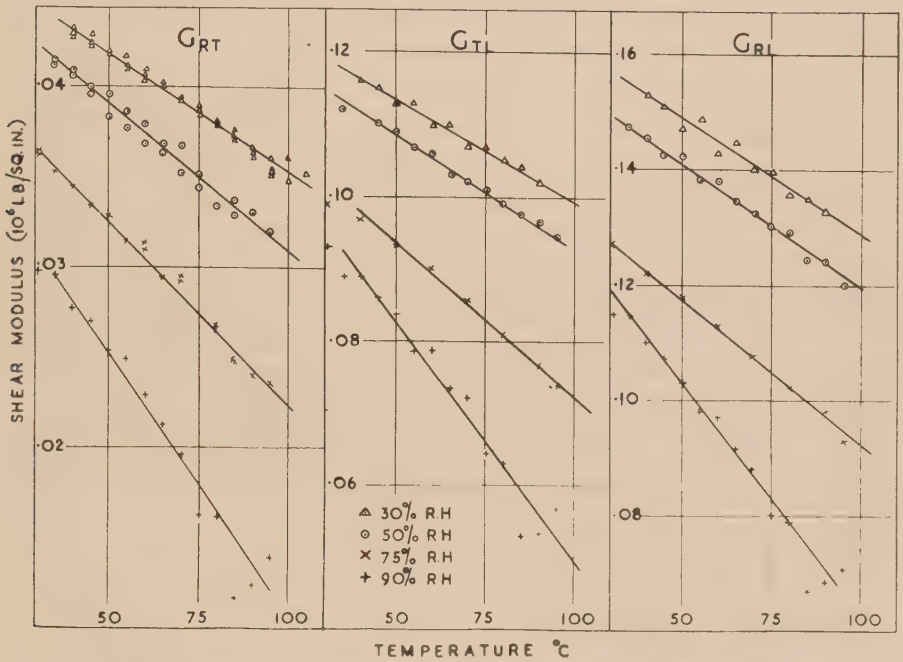


FIG. 2. EFFECT OF TEMPERATURE ON SHEAR MODULI OF BEECH

In each the observations have been represented by a straight line; there is some evidence of curvature at the higher humidities but it is small and hardly greater than experimental error. The experimental error appears to be greater at the higher temperatures and humidities since the scatter of the results is greater under these conditions.

Assuming a straight line relation, the equation for the shear modulus is: $G_r = G_t [1 - a (T - t)]$, where T and t are temperatures in °C., T being the higher. Values of the temperature coefficient a are given in Table I, which shows that the temperature coefficient a increases rapidly at high humidities, and at a given humidity the temperature coefficient of G_{RT} is somewhat greater than that of G_{TL} and G_{RL}. The percentage change in modulus for a temperature change T — t is simply 100 a (T — t), and the percentage change for a 10° change in temperature is also given in Table I. The values vary from 2 to 3 per cent at 30 per cent relative humidity to 7 to 10 per cent at 90 per humidity, and if the accuracy required is greater than this, then either the temperature during the measurements should be controlled, or else the results should be corrected to a standard temperature, as suggested by the Australians.

TABLE I

Values of a

Strip Modulus	1 G_{RT}	2 G_{RT}	3 G_{RT}	4 G_{RT}	Mean G_{RT}	*% Change G_{RT}	2A G_{TL}	*% Change G_{TL}	4A G_{RL}	% Change G_{RL}
% R.H. 30	·0032	·0032	·0032	·0031	·0032	3·2	·0032	2·3	·0026	2·6
50	·0039	·0039	·0040	·0039	·0039	3·9	·0029	2·9	·0033	3·3
75	·0057	·0058	·0060	·0059	·0059	5·9	·0041	4·1	·0042	4·2
90	·0103	—	·0097	—	·0100	10·0	·0073	7·3	·0075	7·5

* For a temperature change of 10°C.

It should be noted that the temperature coefficients given above are at constant relative humidity. Since the equilibrium moisture content of wood at a given relative humidity falls with temperature, the temperature coefficients at constant moisture content will be rather greater than those in Table I. The next stage in the investigation will be to attempt to derive temperature coefficients at constant moisture content, using for the purpose isothermals at different temperatures measured some years ago by Seasoning Section. Experimentally, measurements are now being made on oak, and it is hoped ultimately to modify the method so as to allow the effect of temperature on the Young's moduli of wood to be measured.

Advisory Work in Physics

Although the answering of enquiries is not a major commitment of the Section, those which are received are often of considerable interest, and may need experimental work, or a search of the literature to provide an answer.

In connexion with the design of a veneer conveyor, an enquirer required the coefficients of friction of gaboon, birch, beech, maple, makoré and afara against aluminium and canvas-rubber belting. As no information was available, some measurements of the coefficients were made. The simple theory of friction requires that the coefficient should be independent of area of contact but this was not found to be so, since the coefficient became smaller the smaller the area of contact. The results also showed considerable scatter. The provisional information supplied was satisfactory to the enquirer, but it has not yet been possible to pursue the matter further.

Among other outside enquiries were the following:

The effect of low temperatures on the strength of wood; the methods available for controlling humidity in enclosed spaces; the detection of metal in timber, to avoid damage to woodworking machinery; the use of wood as an electrical insulator; the dilution of salt solutions by the water in wood; the use of wood for musical instruments; the methods available for determining the density of decayed wood.

In addition, the services of the Section have frequently been called upon

by other Sections in matters relating mainly to the design, construction and maintenance of apparatus. The major items have included:

Design and winding of coils for electro-magnetic release on an impact tester; design and winding of coils for safety release on saw feed; testing a strain gauge bridge designed for power measurement, and examining the possibility of amplifying the output; testing an inductance bridge designed for power measurement; tests on the effect of load on the speed of rotation of a cutter head; collaboration in experiments on the effect of ultrasonics on wood-destroying insects; design and construction of a glass apparatus for the vacuum impregnation of wood on a laboratory scale.

SEASONING

Kilns and Kiln-seasoning

Tests in Large Kilns. During the early part of the year, the large kilns were employed for the seasoning of gift consignments of timber to be used for the re-furnishing of the House of Commons. Small parcels of timbers such as iroko, 'African walnut', mayflower, and loliondo, were seasoned and conditioned for the furniture of the new House, and as already mentioned most of these presented difficulties arising from the fact that they contained a wide range of thicknesses and often a considerable variation in initial moisture content. The loliondo proved to be particularly refractory and some honeycombing developed in a few of the thicker planks, despite prolonged and careful seasoning. Other loads of timber dried in the large kiln units included 2-inch East African camphorwood, which dried slowly but well, 1-inch agba, and 3-inch afzelia.

Tests in Small Kilns. The intermediate and model kilns have again been employed mainly for tests on exotic timbers, and the seasoning properties of no less than 15 different species have been tested in the course of the year.

Several loads of test material for other Sections of the Laboratory have been dried in the intermediate kilns, including a load of $2\frac{3}{8}$-inch abura for match-making trials.

In co-operation with a firm of timber merchants, tests were made in a model kiln on the drying of pencil cedar slats with the object of obtaining information which would assist the firm to design suitable plant for installation in East Africa.

New Kilning Methods and Equipment. As a direct result of a visit to America sponsored by Economic Co-operation Administration to study kiln-drying procedure in that country, considerable attention is being paid to the possibilities of expediting the seasoning process by a revision of the normal drying schedules. Tests on the lines of the so-called " stress schedule " method have been undertaken in co-operation with a furniture firm in High Wycombe. In this method, changes in the drying conditions are based rather on the behaviour of casehardening test prongs than upon the actual average moisture content of the kiln samples. This method as applied in practice in America usually involves during the early stages comparatively mild drying conditions followed later by an unusually rapid and marked rise in temperature and drop in humidity when the drying has continued beyond a certain point. The results to date have been somewhat conflicting and arrangements are being

made to obtain material with which to test the possibilities of the method in more detail at the Laboratory itself.

Automatic kiln control equipment is installed in almost every modern kiln unit in America and always this includes a device for the automatic control of the air-venting arrangements. Such a device, though not essential for accurate control of the kiln and seldom incorporated in automatic control equipment employed in this country, probably leads to an overall reduction in the steam consumption as compared with the normal manual control of the venting system. With a view to obtaining first-hand information on this point, automatic venting equipment has been purchased and is to be fitted to one of the Laboratory's kilns. In addition, a three-bulb temperature control instrument specially designed to function effectively irrespective of the direction of air circulation has been obtained and is to be installed for testing in a kiln.

Radio Frequency Drying

Work on this investigation has been limited to a number of miscellaneous experiments such, for example, as the drying of beech squares 8 in. × 8 in. in cross-section. These were dried from the green without checking or honeycombing in periods of less than 2 hours. Abnormally high shrinkage occurred, which, however, could be reduced somewhat by a final steaming or reconditioning treatment. The possibilities of drying thick baulks of aircraft spruce were investigated, but it was found that this species was very difficult to dry (by the boiling method) without bursting. Semi-dried and some green material was seasoned satisfactorily by this method using a very low power input, but drying periods up to 14 hours were then involved with a probable adverse effect on the strength characteristics. Even then, it was not possible always to complete the process without degrade from bursting. Samples of a number of exotic timbers have been tested as they became available but, with few exceptions, these either burst or charred as a result of the treatment to which they were exposed. Apart from miscellaneous tests of this type it is probable that little further work will be done on R.F. drying at the Laboratory in the immediate future.

Air-seasoning

As a supplement to the work recently carried out on the kiln-seasoning of thick oak, a load of 4-inch quartered green oak has been piled for air-seasoning so that data relating to drying rates, shrinkage, degrade, etc., may be obtained and compared with those obtained from the kiln-drying of similar material.

A consignment of softwood telegraph poles has been stacked for air-seasoning before impregnation by the Wood Preservation Section. A long-pronged electrode has been specially designed for testing the moisture content of the poles by electrical means.

Passage of Liquids through Wood

Enquiries connected with barrels, vats, boats, etc., have indicated the need for obtaining reliable data on the distribution of moisture across the section of a piece of timber freely exposed to the air on the one face, but in contact with water on the other. Vat staves, for example, need to have and normally will have a high moisture-content value on the inside face so as to keep the joints closed but, unless they are free to dry and attain a reasonably low

moisture-content value on the outside face, this face which is exposed to the air will be very liable to decay.

With a view to investigating moisture gradients and also to help determine an optimum moisture-content average for various kinds of vat and barrel staves shallow trays have been made from various species and thicknesses of timber. These trays are kept filled with water and the undersides fully exposed to the drying effects of air under various humidity conditions. After long and varying periods of exposure these trays are cut open and moisture distribution tests made across the section. Results till now have indicated that a high moisture concentration tends to form near the wetted face, but that the bulk of the timber assumes moisture values not greatly in excess of the equilibrium moisture content on the face exposed to the air. The effects of hygroscopic liquids on the moisture gradients and hence on the expansion or shrinkage that might be occasioned in barrel or vat staves are also being investigated.

A load of 3-inch afzelia is being seasoned for a firm of vat makers in a co-operative experiment to determine whether this timber when dried to an average moisture content of 15 per cent will prove a suitable substitute for the softwoods usually employed.

Performance Tests on Doors

Preliminary trials have been made on flush and panel doors in the new door testing building and the results have been analysed. The principal defect which developed was curvature from head to foot of the doors, and this was observed to be greater on the flush type than on the panel type. A second test on a batch of flush doors of different kinds, some with hardwood facings, was completed.

The Preservation of Paintings on Wood Panels

The series of tests carried out in co-operation with the National Gallery has been completed and a report written on the work done and the results obtained. It was clearly demonstrated that the coating of gesso normally applied to that face of a panel which is to be painted can impose considerable restraint on the movement of wood, thereby inducing curvature of the surfaces. It would appear, therefore, that flexing can only be inhibited effectively either by coating equally both faces of the panel with gesso, or by regulating the surrounding air conditions so that there is virtually no change in the moisture conditions of the wood.

Miscellaneous Work

At the request of firms interested in such products, samples of imported floor boards of laminated construction and of certain types of wallboard have been subjected to cyclical changes of air conditions and their resulting behaviour and dimensional changes determined.

Advisory Work in Seasoning

The number of enquiries received during the year in connection with seasoning and bending amounted to just over 900.

Close co-operation was maintained during the year with firms interested in seasoning and bending, and 90 visits were made. Of particular interest in this connexion was the co-operative work undertaken for a firm of rule manufac-

turers faced with the problem of accelerating the seasoning of large quantities of Maracaibo boxwood slats. Special tests were carried out at the Laboratory on the piling method and drying schedule to be adopted and recommendations made as to a suitable type and design of kiln plant for use on a commercial scale. A kiln of the recommended type was built and a visit was made to the firm concerned to supervise the initial run and advise upon the general procedure. Results were in the main satisfactory, apart from some staining, revealed only on machining, that occurred on several slats. To overcome this defect a milder drying schedule has been suggested which, though successful till now, may yet need to be revised should further similar trouble develop.

WOOD BENDING

The Bending of Tropical Timbers

The testing of tropical hardwoods for bending properties in both solid and laminated form has again been given priority and, during the year, some twenty-seven species have been tested. None was found to be comparable in bending properties with such woods as beech or ash, but mansonia proved to be a wood which, though variable in character, possessed reasonably good bending properties.

In view of this failure to discover tropical species with inherently good bending properties, attention was directed to the development of a process whereby their bending properties could be improved. Tests had shown that certain synthetic resin glues would withstand steaming treatments and also the stresses and strains induced in a steamed assembly during bending without breakdown of their adhesion occurring. This enabled a process to be developed which differs from the normal in that a layer of a good bending wood such as beech is glued to that face of the material having inferior bending properties which will be in compression during bending.

Tests of the new process have been carried out on danta, and several types of furniture bends have been made using utile, Sitka spruce, dahoma and guarea. The results showed that by using the new process the bending properties of all species tested were markedly improved. With danta, for example (Plate 1 (A)), it was found that by the addition of a beech supporting layer of a thickness no greater than $\frac{1}{16}$-inch, a reduction in limiting radius of up to 65 per cent could be achieved, corresponding to an increase in maximum compressive strain of from about 7 to 19 per cent.

The process has been published and exhibited and a display has been prepared for the Festival of Britain.

Further development work has indicated that similar results may be obtained by substituting for the layer of beech a lamina of almost any species, if it is placed with the grain direction at right angles to the length of the piece that it supports.

Routine Testing

Tests on thirty hardwood species have been carried out to determine their bending properties in the cold state, as is required for the production of laminated bends. Of the species tested, mansonia was again found to be the only one with properties somewhat similar to those of ash, birch, etc., which are the woods commonly used in laminated work.

Effect of Moulds on Bending

Tests relating to the influence of infection by moulds on the limiting radii of curvature of beech laminae have been carried out. The laminae were inoculated with mould fungi such as *Chaetomium globosum*, *Trichoderma viride*, and *Paecilomyces varioti* but in these experiments the brash failure such as is found with wood-destroying fungi has not been observed and, indeed, the effect of the moulds on the bending properties has so far proved to be negligible.

Advisory Work in Wood Bending

Work undertaken in connexion with enquiries from the trade has included investigations into methods employed for the manufacture of radio cabinets, and the causes and prevention of breakages in the bending of barrel staves, furniture parts, etc. At the request of a firm, a method of producing a particular type of furniture bend was developed and, by its adoption, the number of rejects from breakage during bending was very considerably reduced.

TIMBER MECHANICS

Comparative Tests

The testing of Empire species has proceeded during the year on an increased scale, and under a new plan described below. Species tested in major consignments in the green condition were sterculia, pterygota, berlinia, makoré, agba, binuang, muhimbi, and nyankom. Matched material is now seasoning for tests at 12 per cent moisture content in order to provide full data concerning these species. Minor consignments tested green comprised muninga, mgongo, mkwaju, mbembakofi, and mjembe, together with a few planks of kokrodua.

Minor consignments tested at 12 per cent moisture content included mtondo, mjombo, mchenga, dahoma, danta, idigbo, utile and greenheart.

Test Methods

The standard scheme for testing the strength of timber has, in the past, been based on test samples of 2-in. square cross section. This scheme was initiated in the United States of America early in this century and has been adopted in its general principles by all the English-speaking timber-testing authorities.

A scheme of testing generally similar in pattern but based on test pieces of 2 cm. square cross section, and with the test procedures rather less detailed than under the American system, was developed in France in 1917. The subsequent extensive adoption of this scheme in continental countries and elsewhere was facilitated by the production on the Continent of a convenient universal type testing machine specially designed for these tests.

A standardized scheme of testing has been the subject of considerable discussion at recent international conventions held under the auspices of F.A.O. and the outcome has been that both sizes have been accepted as standard, and test details, mainly corresponding to the American system, have been agreed, which should ensure comparability of results obtained from the two sizes of test pieces for the important properties of compression and bending.

Experience at this Laboratory has shown that the 2-in. square specimens have considerable disadvantages compared with the smaller specimens. For instance, whilst it is comparatively easy to obtain test samples free from defects from large trees of virgin timber, for which the scheme was originally devised,

clear test pieces of the requisite 2 ft. 6 in. length for the important tests of static and impact bending are not readily forthcoming from the smaller European softwood logs without considerable waste owing to the prevalence of natural defects, particularly knots. Apart from economy of material, the smaller test pieces have other advantages which facilitate test procedure and enable results on seasoned material to be obtained more quickly.

The strength figures from such tests on small clear specimens of whatever size are not directly applicable to timber in structural sizes. Their main purpose is to enable comparison to be made between species and to investigate the effect of various factors on the strength of wood. For the first purpose it is highly desirable that the results should be directly comparable not only within a testing station but also as between different testing stations. For the second purpose standardization is not so necessary as it is always possible, and indeed essential, to carry out matched control tests. It is much simpler to obtain such matching in the 2-cm. size test specimens than in the 2-in. size specimens and indeed for *ad hoc* tests, where the size of the material is limited, it is often impossible to obtain 2-in. square test material. For practical reasons it is desirable, if at all possible, to adopt one testing size for both purposes.

During the year under review tests have been carried out on a number of species according to both schemes of testing. If there should be reasonable correlation enabling direct comparison to be made with previous results, it is intended in future to adopt the 2-cm. square size as the standard for this type of testing.

The Use of Timber in Building

In the field of building, activity has been mainly confined to the designing of permanent equipment for structure testing, and to advisory work. The design of the loading units has been completed, and the necessary components have been ordered. Each unit will consist of a hydraulic jack anchored to a hydraulic capsule of 10 tons capacity, connected by flexible pipes to a control panel incorporating pumps and pressure gauges.

The new structure-testing laboratory now nearing completion is equipped to permit the testing of structures occupying an area up to 38 ft. × 26 ft. under a maximum load equivalent to a distributed load of 3 cwt. per sq. ft., and the testing of trusses, girders, etc., up to 78 ft. long, and arches up to 38 ft. span and 26 ft. high, under loads up to a maximum of 1½ tons per foot of span.

A number of schemes for timber houses and for various forms of timber roof have been reviewed at the request of other Government Departments, and modifications have been suggested in some instances.

The part of the Technical Appendix to the Housing Manual concerned with timber floors and roofs has been revised for the Ministry of Works, and some assistance has been furnished in connexion with the revision of the Timber Economy Memorandum.

The Strength of Shear Connectors

The investigation of the strength of 2½-in. diameter "Bulldog" shear connectors, which was postponed from 1949 pending the commissioning of a new specially equipped testing machine, has now been completed. The arrangement is shown in Plate 1 (B). Data were obtained regarding the strength of the

joints in compression and in tension, the latter with the connector at a series of distances from the end of the member in order to determine the optimum value. A duplicate series of tests was carried out on joints made with bolts only, in order to determine the respective contributions of the bolt and the connector.

The customary method of measuring the movement of connector joints under load has been by means of a dial gauge mounted on the face of the test joint, and readings are therefore subject to error in the event of angular movement of the component members of the joint. As tests showed that angular movement was in fact liable to occur, an extensometer was constructed to eliminate the possiblity of error by averaging the movement on opposite sides of the joint. This extensometer was arranged to work with the microformer equipment of the testing machine, in order to provide an automatic load/movement record of the test.

For testing the tension joints use was made of new grips designed at the Laboratory and incorporated by the makers of the testing machine. These grips are pneumatically operated and hold the wood by means of small chisel-section teeth and, with them, unlike the normal wedge grips, the lateral pressure is independent of the axial load. The new grips have proved satisfactory in use and have enabled tension tests to be made without the test piece slipping and without its being crushed by excessive side pressure.

Performance Tests of Doors

Further exploratory torsion and slamming tests have been made on doors to provide a basis for the establishment of performance tests to replace existing specifications based on constructional materials and design.

Miscellaneous Tests

Ad hoc investigations at the request of industry have included tests of laminated ash for tennis racket frames, textile bobbins with reference to flange bursting strength; hickory and ash for tool handles; Danish ash for cricket stumps; oak with reference to brittle failures during manufacture for furniture; yang with reference to the failure of a motor-body bearer, and decorators' platforms with reference to modified tension reinforcement.

Abrasion

The effect of different drying treatments on the wearing qualities of home-grown oak has been investigated. Abrasion tests indicate that neither the relatively high temperatures employed in kiln-drying, nor an appreciable over-drying to a low moisture content with subsequent re-wetting, is detrimental to the resistance of the wood to wear.

Standard tests were carried out on two hardwoods, wallaba and kwao or kanluang. Both woods show promise for high-class flooring. At the request of its manufacturer, further tests were made on a special type of end-grain Burma teak flooring.

Advisory Work in Timber Mechanics

Advisory service to other Government Departments and to the Timber Development Association in connexion with timber in housing has been given considerable attention. In addition, a wide range of enquiries concerning

miscellaneous aspects of strength has also been dealt with. The total number of such enquiries during the year was 170.

A considerable volume of advisory work in connexion with the utilization of timbers for flooring has been undertaken during the year. One hundred and thirty-seven enquiries on matters relating to wearing qualities of hardwoods and softwoods, floor treatments, renovations and finishing, have been answered. The question of substitutes for Canadian maple for heavy-duty and other floors continues to be of importance.

COMPOSITE WOOD

Properties of Plywood Adhesives. Durability Tests

The long-term natural durability tests on plywood adhesives and assembly glues continue. For the adhesives, the second report has been issued on the relative performance of adhesives in lime and in beech plywood, and the first report has been prepared on material exposed for the Laboratory at Port Harcourt, Nigeria, by the Tropical Testing Establishment of the Ministry of Supply. For the assembly glues, a report covering the first three years of the experiment on laminated beams has been written.

The main Series II experiments on the durability of beech plywood fully exposed to the weather are now in their fifth year, and the samples are being systematically tested in preparation for the analysis of results to be made early in 1951. During the same year, the ply-clad frame test units* will also reach their fifth year of exposure, and the ageing tests on British Standard Specification joints will be seven years old.

New material has been added to that already installed in the motor torpedo boat placed at the Laboratory's disposal by Admiralty Craft Experimental Establishment at Gosport. A further addition to this marine durability experiment is a large number of laminated beams simulating built-up stems, chines and keels; these are being housed vertically in an outrigger bolted to the stern of the boat, and will be immersed in the sea to their half length. As an aid to the making of the required hundred beams, special jigs have been designed as part of the Laboratory's study of manufacturing methods. In addition to this particular experiment on glue durability, active liaison is maintained with Coastal Forces on matters pertaining to the construction and maintenance of wooden boats.

The Knife Test

Among the items that have received intensive discussion by the Adhesive Makers' Panel is the revision of British Standard 1203—'Synthetic Resin Adhesives for Plywood'. At present, the specification is based upon the mechanical testing of a particular type of joint cut from beech plywood, and although it is satisfactory in itself, the method cannot be co-ordinated with that now employed in specifications for the manufactured plywood. The Laboratory has proposed that, in addition to beech, any appropriate species can be used in making the plywood test-pieces with the adhesive under examination, and that the knife test (Plate 2) should take the place of the mechanical test. Systematic observations over many years have shown the knife test

* The details of these frames were given in the Report for 1946. Briefly, they are softwood frames to which are bonded plywood sheets. These have their edges protected in various ways, and each frame is exposed to full weathering on one side, and on the other to outdoor air, but not to sun or rain.

to be even more informative than the strength test upon the quality of the bond. It is also immediately applicable to any species, whereas with the strength test, for timbers other than beech or its equivalent, new standards of failing load would have to be established—a task of considerable magnitude. The knife test is open to the objection that it is qualitative, difficult to describe in writing, and requires experience in its interpretation, but to demonstrate its practicability the Laboratory has held a course for industrial technicians at which a high degree of concord was established, and discussions upon the revision of the specification are now continuing.

Classification of Adhesives

For the last three years the durability of adhesives has been under discussion by the Composite Wood Corresponding Committee of the Commonwealth Conference Standing Committee on Forest Products, and the exchanges show an almost complete unanimity of opinion. This is of considerable importance, because the six Laboratories concerned have worked independently and used for the experiments many different brands of adhesive of each type. The Sub-Committee has agreed upon the following classification for adhesives, the basis being the performance of comparatively small, unprotected joints upon which the environmental conditions can operate without hindrance.

Group I—Weather-proof adhesives

Adhesives that by systematic tests and their record in service have proved virtually indestructible by weather, micro-organisms, hot and cold water, and dry heat. Such glues are more durable than the wood itself.

(Examples:—phenolics, resorcinols and melamines.)

Group II—Moisture-resistant adhesives

To this group belong those glues which offer considerable resistance to severe conditions for a limited time, but which deteriorate slowly, and ultimately fail completely. They are, however, satisfactory under conditions less exacting than those applicable to the Weather-proof group.

A wide range of glues is included in Group II and it is convenient to sub-divide them according to their resistance to micro-organisms. This term covers moulds and bacteria, but for convenience of reference, 'mould' will be assumed to include bacteria.

Group IIA—Moisture-resistant—Mould-proof.

(Examples:—Normal and fortified urea resins. Heavily extended phenolic glues.)

Group IIB—Moisture-resistant—Mould susceptible.

(Examples:—casein, soya, blood, heavily-extended urea resins.)

Generally speaking, glues of Group IIA retain a greater proportion of their joint strength when wet than do those of Group IIB.

Group III—Interior adhesives

Adhesives such that joints made with them fail completely under the action of water or dampness alone.

(Examples:—animal, starch, poly-vinyl emulsions.)

Properties of Plywood

Small-scale work has continued on the causes of distortion of plywood during manufacture. The results have been considered by the Plywood Research

Panel and a programme agreed for the continuance of the tests upon boards five feet square. In addition to this systematic work, *ad hoc* tests have been made upon warped panels received from commercial sources to ascertain the cause of the trouble.

Trials of Timbers for Plywood Manufacture

The method for testing and assessing timbers for plywood manufacture has been agreed by the Plywood Research Panel. Matters for systematic investigation include an appraisal of the timber in log form and all information on its availability, the best ways of ' processing ' the wood, i.e. pre-treatment, best lathe-setting for peeling, drying characteristics, edging and splicing, glue-taking characteristics and optimum spread for several types of resin, and the most suitable pressing schedule. When these matters have been determined, yield trials are conducted whereby losses in conversion from log to plywood are measured at each stage of processing. Full details of the scheme are given in a Manual, issued for use in conjunction with a standard form of report. The scheme has the advantage of flexibility—each section is complete in itself and emphasis can be laid on particular aspects according to the probable uses of the timber. Thus one species may be suitable for high-grade commercial plywood, another be more useful for core veneer, whilst a third might appear to be a substitute for Canadian birch for aircraft plywood. With logs of 2 ft. to 3 ft. diameter, about 300 cu. ft. are needed for a full test, but less can be used if limited data are sufficient. Including the preliminary tests made whilst the scheme was being developed, twenty-three timbers have been examined and reports prepared.

Special Heating Methods for Glue-setting

Low Voltage Heating. In contrast to the radio frequency method, in which heat is generated within the work, low voltage heating and similar sheet-element systems rely upon the slower process of conduction from a surface. Where, however, the glue to be set lies close to the face, as in veneering, such methods have several advantages and are considered for adoption where radio frequency might otherwise have been the first choice.

The use of the low voltage method has in the past been restricted to narrow work such as laminated bends, in spite of the great convenience offered by the simple, robust sheet-metal elements, which are safe to touch because they are operated at a voltage no higher than that of a car battery. This restriction in width was partly owing to the difficulties in handling the very large currents needed for wide elements and partly to the fact that non-uniform heating is very liable to occur. The mechanical and electrical problems involved in the use of these elements have now been investigated, and by suitable design of plant the method has been reduced to a practical process for heating areas up to 3 or 4 ft. in width, thus providing, for example, a means of doing hot-press veneering work in a simple cold press. Curved work is, moreover, as easily treated as flat.

Power concentrations of 200 to 400 watts per sq. ft. are required, which for large areas means the consumption of tens of kilowatts, but the equipment required is compact and comparatively inexpensive. Plate 3 shows the transportable 18 kW step-down transformer which was used in the investigations; it is only 4 ft. $6\frac{1}{2}$ in. high, including the switchgear chamber. Power is taken

from it by slender water-cooled cables attached by water-cooled plug-in connectors (which were developed at the Laboratory) capable of carrying over 2,000 amperes. By these means, quick attachment can be made to the ends of the heating elements, when these have been loaded into the press, together with the veneer assembly.

Uniform heating is assured by suitable choice of element material such as certain types of alloy sheet or woven iron wire mesh, combined with the provision of a sufficiently heavy copper electrode at each end to distribute the current. From theoretical considerations the minimum size for these, which varies according to the dimensions and the material of construction, was calculated, and the theoretical work was confirmed in experiments which gave temperatures uniform to within $\pm 1\frac{1}{2}$°C. at 75°C.

Radio Frequency Heating. In the radio frequency studies attention has been concentrated on testing the limiting behaviour of glues in joints heated by the glueline method. A graphical representation of the results has been evolved in which the setting conditions, *viz.* the voltage applied to the sample and the duration of the treatment, are plotted against one another (Fig. 3). On such a chart, various zones can be delineated showing the different modes of behaviour of the glue. Round the perimeter are zones in which the adhesive does not set, or breaks down by arcing, or gives weak joints for other reasons. The boundary lines meet and leave a central zone of " safe setting conditions ", whose extent is a measure of the suitability of the adhesive for setting by radio frequency methods.

On the experimental side, the standard five-ply beech block test-piece previously evolved for this work has been modified and improved, and the quality of the bond is now gauged by measuring the force needed for splitting open the glueline. Taking this in conjunction with the graphical method of assessment, a full testing technique has thus been developed, and has been applied to a number of synthetic resins and other types of adhesive. The results show the urea formaldehyde glues to behave satisfactorily, but the phenolic and resorcinol types tested are very prone to breakdown by arcing. The results have also indicated in what directions the glues could be modified to render them more satisfactory.

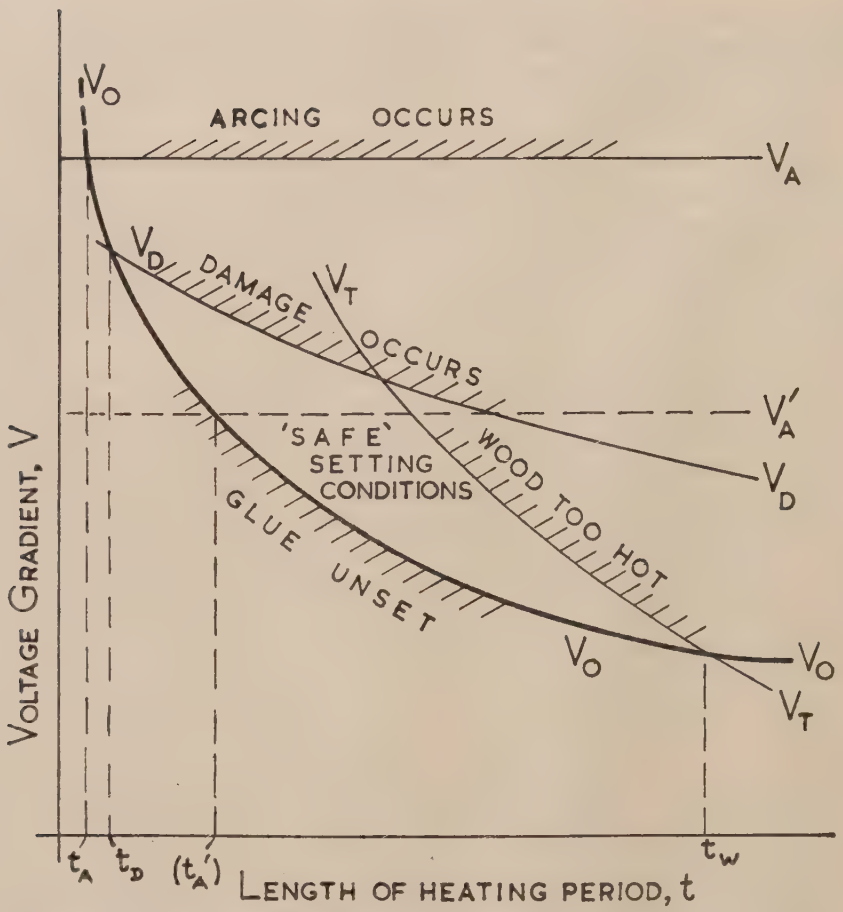
A large number of samples has been made for ageing tests, in which the effects of radio frequency heating will be compared with cold-setting in joints stored for periods up to 10 years.

At the request of the Radio Frequency Panel a summary has been prepared of the work on glueline heating. It sets out briefly the effects of the numerous factors which have been found to influence the radio frequency behaviour of glues, and describes the performance of each of the commonly used types of adhesive. The summary has had a wide distribution in the furniture industry, and will be published in the technical press.

Attention has now been turned to the related process of stray field heating, in which there is no direct contact between the radio frequency electrodes and the gluelines, but in which some selective heating of the glueline still occurs.

Studies on Plant and Machinery

The study of the mechanics of peeling has continued and the limited circulation of a report in 1949 has brought many enquiries from industry this year.



Idealized diagram of the behaviour of an adhesive in a joint heated by the radio frequency glueline method. Any given radio frequency treatment is represented by a corresponding point on the diagram, and the various zones indicate the resultant state of the joint. Lines V_a and V_a^1 show the effect on the "safe setting zone" of having a high or low resistance to arcing.

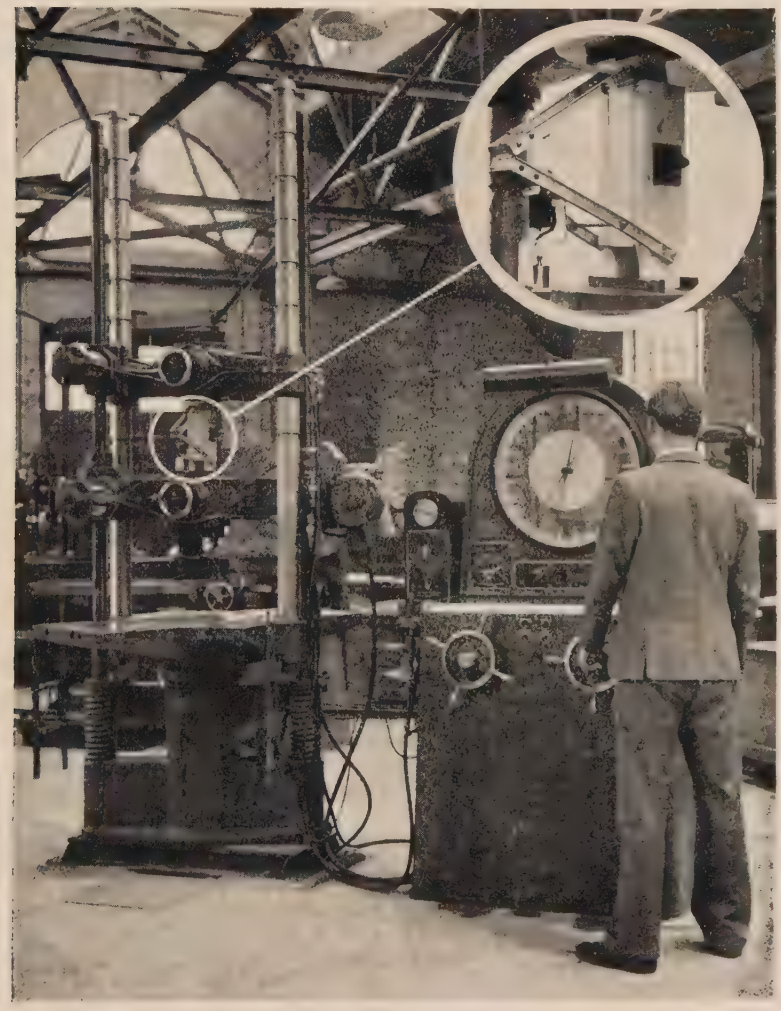
FIG. 3. BEHAVIOUR OF AN ADHESIVE UNDER RADIO FREQUENCY GLUELINE HEATING

New handling plant has been designed and made to deal with both continuous and discontinuous veneer from the lathe, such plant being necessary both for a study of its functioning and also to handle the output of material of widely varying quality for the processing and yield trials on new timbers.

The drying of veneer has been intensively studied, particularly with regard to the variation in moisture content between and within individual pieces. Means of reducing this by modifications to the dryer are being considered, but for the present it has to be accepted that wide variations exist, and that equalization must be effected by storing the veneer. For practical reasons, the use of piling sticks or finger racks to give free circulation of air is ruled out, and the veneers must be put into solid piles. The rates of equalization and of change in mean moisture content under these conditions have been determined

Bend A. 1-in. stick of solid Danta.
Bend B. $\frac{15}{16}$-in stick of solid Danta with $\frac{1}{16}$-in. beech supporting layer.

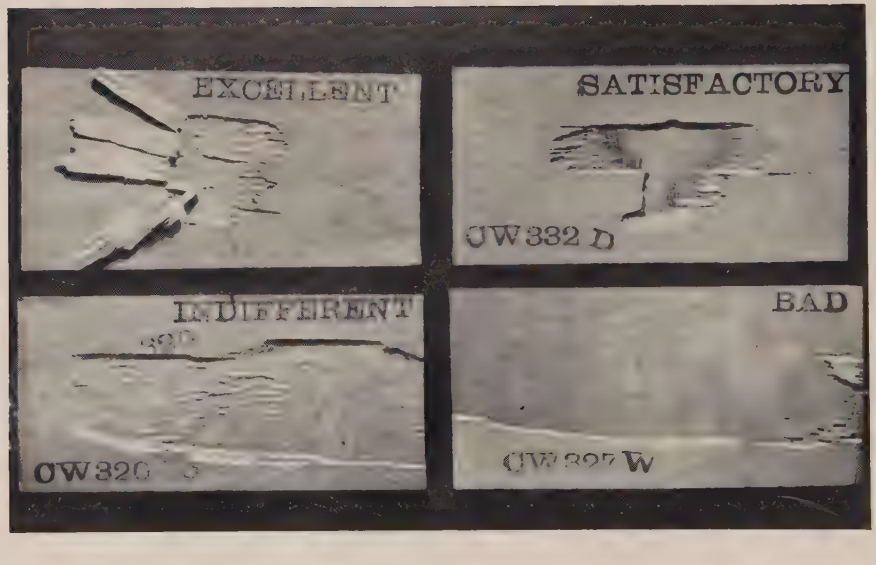
(A) BENDS OF DANTA MADE WITH AND WITHOUT A SUPPORTING LAYER OF BEECH



(B) TESTING TIMBER CONNECTORS

PLATE 1

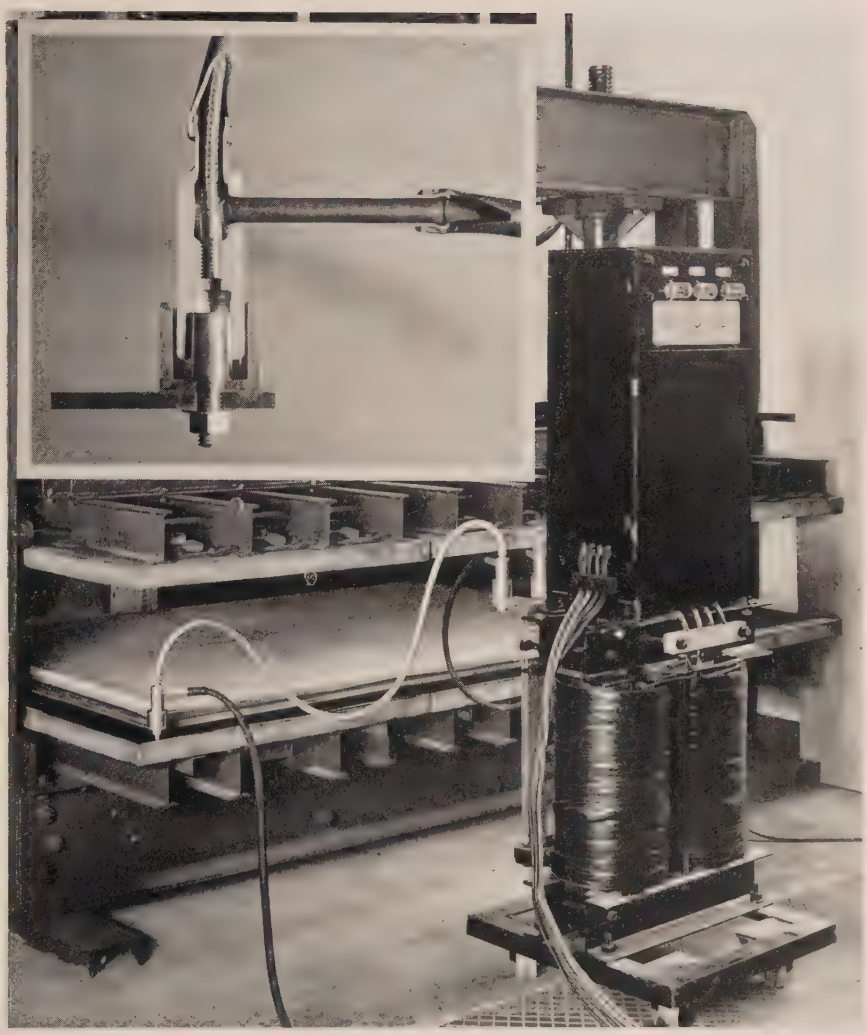
The tool and the method of application



Four degrees of bond quality in beech plywood as shown by the knife-test

KNIFE-TESTING PLYWOOD FOR QUALITY OF ADHESION

PLATE 2



The use of low voltage heating for applying veneer to two sheets of plywood, arranged one on either side of a sheet-metal heating element. The ends of the element are connected to the transformer (right) by water-cooled cables and coned plug-in connectors, of which a sectional model is shown inset. The transformer is capable of 18 kW. output. The upper platens of the screw press have been raised for the purpose of the photograph

LOW VOLTAGE HEATING APPLIED TO LARGE AREAS

PLATE 3

A continuous-operation oven heated by infra-red lamps which rapidly dries veneer samples for moisture-content determination

MOISTURE-CONTENT DETERMINATION ON VENEERS

PLATE 4

for 0·063-in. veneer of two species. As the work has involved thousands of moisture content determinations on veneer samples, speedily obtained results were essential. Plate 4 shows an infra-red-heated continuous-operation oven designed by the Laboratory. It takes standard samples 6 in. square cut from full-sized sheets, and, including time for weighing and computing, a moisture content can be determined in 8 to 10 minutes, and a rate of 40 per hour maintained. Direct-reading electrical instruments are, of course, much quicker, but unfortunately they are completely unreliable when used with veneer straight from the dryer.

The study of glue mixing, originally begun at the request of the casein glue manufacturers, led to the evolution of special continuous plant for casein glue mixing, operating on new principles. This has been improved during the year, and rendered suitable for the mixing of liquid resin glues with their hardeners. Plant for delivering materials to the mixer in the appropriate proportions, which was designed last year, has now been built and is undergoing tests in conjunction with the mixer. The process has been patented.

Considerable attention has been directed to the technique of spreading glue upon veneers and to ways of improving the spreader itself. Some of these improvements have been adopted industrially. Other minor but important additions to the plant have been a loader of a type suitable for large multi-daylight presses, caul-handling racks and an induced-draught caul cooler.

The activities of the Composite Wood Sub-Committee of the Commonwealth Conference Standing Committee on Forest Products have continued and the third and fourth collations have been circulated to the six Laboratories concerned. The agreement on a classification for adhesives has been mentioned; other matters upon which information and views have been exchanged include the mechanics of peeling, the assessment of veneer quality, methods of appraising the value of timbers for plywood manufacture, preservation treatments for plywood, the efficiency of surface coatings, and radio frequency heating. Specifications in the several countries have been compared and an arrangement has been made whereby material for ageing or weathering tests can be exchanged between the Laboratories when the need arises. A further valuable function of the Committee is the informal exchange of research programmes.

Advisory Work in Composite Wood

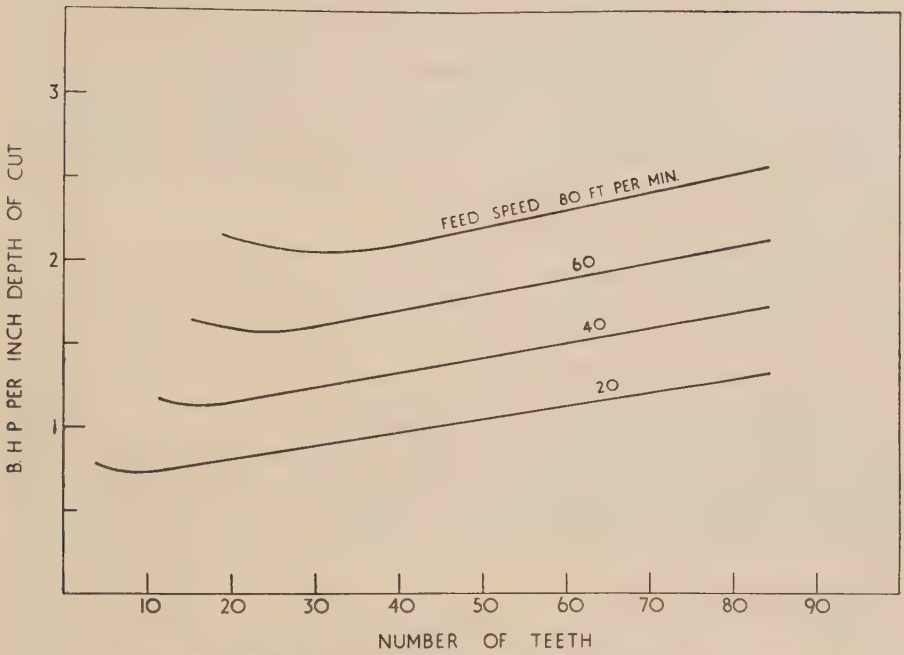
Enquiries for information from industrial sources have totalled about 370, and the tendency for the number to rise continues. This figure includes 36 on radio frequency matters.

WOODWORKING

Sawing Research

Problems in sawing are usually concerned with the correct tooth shape and spacing of the tooth, cutting speed and rate of feeding to be employed in dealing with a particular class of timber; and information on the relationship of the various factors in the cutting conditions and the saw performance is needed to provide the solutions. These matters have been investigated at the Laboratory and the approach has been both theoretical and practical. An analysis of the cutting action of circular saw teeth was published in 1947 and further mathematical studies have been made both for circular and band saws. It has been found that one of the most important variables is the depth of penetration of individual

teeth. The amount of wood removed per tooth depends on this factor and should be limited by the following conditions: the load on each tooth should not be excessive, the volume of sawdust produced per tooth should not exceed the gullet space available, and with spring-set teeth, their inner tips should not engage with the wood. For band saws, the depth of penetration (chip thickness) is given by the formulae $t = \frac{pf}{c}$ for swage-set teeth and $t = \frac{2pf}{c}$ for spring-set teeth, where p = pitch (in.), f = feed speed (ft./min.) and c = cutting speed (ft./min.). For circular saws, the simplified formulae are $t = \frac{pf}{c} \sin \omega$ and $t = \frac{2pf}{c} \sin \omega$ respectively, where ω is the angle locating the position of the particular tooth from a vertical reference line. The value of t will be a maximum, therefore, where the tooth is near the machine table, for ω is then nearly 90° and $\sin \omega = 1$ approximately. Experimental work on circular rip saws has indicated the suitable upper limits of chip thickness for various sizes of saw. For example, with saws of 24 to 30 in. diameter and standard gauge this thickness should not greatly exceed 0·03 in. for moderately dense hardwoods, 0·04 in. for the lighter hardwoods and about 0·05 in. for softwoods. It is thus possible to gain some idea of the maximum feeds that can be permitted for saws with different numbers of teeth. With a spring-set 26-in. saw running at 10,000 ft./min. and cutting a mild hardwood, the appropriate formula becomes $f = \frac{200}{p}$ so that a feed of up to 100 ft./min. should be permissible with forty teeth on the saw, though the size of the timber being cut would enter into the matter (see below). This limiting factor of the loading of the teeth becomes increasingly important as fewer teeth are used. Series of tests have been carried out with saws having from 4 to 80 teeth, i.e. 4, 8, 12, 16, 20 and so on. For identical conditions of operation, *viz.* the same rim speed, feed speed, depth of cut, angle of hook, kerf width, etc., it was found that the power required by the saw decreased linearly for all practical purposes over most of the range, as the number of teeth was reduced (Fig. 4). With each of these saws, however, there was a critical feed speed above which the teeth became overloaded, as was shown by local blueing of their tips. A 26-in. saw with four spring-set teeth has a pitch of 20 in. and, according to the formula for mild hardwoods, the maximum allowable feed speed is 10 ft./min. Such rate of feeding is too low for the saw to be of practical value, for with the feed speed increased merely to 20 ft./min. the chip thickness would be 0·08 in. and the tooth tips would quickly lose temper. There are similar disadvantages in the use of eight or twelve teeth on this size of saw, and it has been shown that the satisfactory minimum number of teeth was twenty-four, as it permitted feeds up to 60 ft./min. for spring-set teeth and 120 ft./min. for swage-set. The feed limits mentioned above could be raised if higher rim speeds were employed, but the more practical application of the use of a few teeth is to the smaller diameter saws. Though the maximum chip thickness has to be reduced slightly, increased feed speeds can be allowed because of the shorter pitch. For instance, a spring-set 12-in. saw with 12 teeth and 10,000 ft./min. rim speed can be used at feed speeds up to 40, 60 and 75 ft./min. respectively for the different classes of timber, and nearly double these rates are possible with the teeth swage-set or tipped with tungsten carbide.



Conditions:—mild hardwood, saw dia. 26 in., rim speed 10,000 ft. per min.

FIG. 4. RELATION OF NUMBER OF TEETH TO POWER REQUIRED BY A SAW

The second consideration in this matter is that the volume of sawdust produced per tooth should not exceed the available gullet space. The relation of the latter to the different variables in the cutting conditions is given by the formula $f = \frac{ac}{3pd}$ where a = area of gullet space (sq. in.) and d = depth of timber cut (in.). It is based on the results of experiments to determine the ratio of the volume of sawdust (when lightly packed) to the volume of solid wood from which the sawdust was produced. Allowance is made for the fact that only a portion of the gullet space, to about three-fifths of the pitch in the case of normal tooth shapes, has effective use in holding the sawdust. Though based on theoretical considerations, this formula may be used with advantage in checking saw performance. In practice, all teeth may not cut equally for various reasons and some gullets will collect less sawdust than others. Under such conditions, the calculated volume of sawdust produced per tooth will then correspond to the average value for all the teeth.

The importance of gullet shape and area on efficient sawdust removal, especially when high rates of feeding are employed, has shown that a knowledge of the behaviour of sawdust in gullets would prove useful. Accordingly a special technique has been developed for observing the movement and distribution of the sawdust produced by teeth when actually cutting. The saw is carefully prepared and run truly in very close proximity to a window of toughened glass. The wood is power-fed to the saw, which cuts to the exact width of its kerf, and thus the conditions of cutting approach those normally

obtaining in practice. The range of the investigation covers feed speeds of 10 to 150 ft./min., rim speeds of 9,000, 10,000 and 11,000 ft./min. and various types of saw. The behaviour of the sawdust is observed and photographed with the aid of high-speed flash equipment. Some information has already been gained on the influence of particle size, presence of gum, condition of seasoning and nature of the wood in this connexion and the studies are being continued.

Rotary Planing

Further experiments have been made in rotary planing to obtain data on power demand and feed resistance at different depths of cut in planing over a range of feed speeds and at three cutting angles.

Routing

A preliminary investigation was undertaken in the routing operation on power requirements under different conditions of cutting. A mechanical brake dynamometer was made and tested for use in establishing the relation of slip and power of the high frequency motor. Improved methods of measurement are under consideration to enable more advanced studies to be carried out.

General Work

Full-scale woodworking tests were carried out on the following timber species:—

Avodiré from West Africa—kiln-dried
Ayan „ „ „ „ „
Dahoma „ „ „ „ „
Essia „ „ „ „ „

Various special types of circular saw have been tested in comparison with saws of normal design. A prototype 10-in. diameter 12-tooth saw for use on a multiple saw bench at fairly fast rates of feeding has been designed and tested.

The development of suitable dynamometers for various experimental machines has progressed. A torsion type has been designed for the direct measurement of power transmitted through saw and cutterblock spindles, and preliminary tests have been made of a torque tube carrying electric strain gauges. Another form of torque dynamometer for use on a boring machine has been designed and constructed, and a special form of feeding mechanism for the latter has been installed. A study has been made of different methods that can be employed for high speed recording of minute varying currents, to determine the most suitable for use with these dynamometers. Other forms of dynamometer have been developed for direct measurement of forces such as the thrust and torque on the wood specimens in boring tests and the feed resistance in sawing, planing and other operations. Previously, hydraulically operated recording devices had been used for such purposes, but they had the serious disadvantage of needing an appreciable displacement of the loaded member of the apparatus to give measurable responses. Such movement resulted in momentary slowing up of the material being fed, with a corresponding reduction in resistance. In 1940, apparatus was devised with which this trouble was largely overcome. The loaded member was supported by a short high-speed steel beam and the deflection of the latter was measured by means of a sensitive dial gauge, which was calibrated to give direct measurement of the

force applied to the beam. This method proved satisfactory but had the drawback that only spot readings could be obtained. Careful consideration was given to the possibility of using some form of electrical recording unit and during this year suitable proprietary apparatus has been acquired. This instrument is designed and normally employed for recording minute differences in the dimensions of machined parts, and it has proved eminently suitable for our purpose. It is capable of recording to an accuracy of less than 0·00002 in., with a total range of 0·0008 in. Stout beams can thus be employed even for relatively light loads and the movement of the whole system can be brought to a minimum.

Advisory Work in Woodworking

Advisory work has continued to be an important part of the Section's activities. It has covered a wide range of subjects—from all aspects of sawmilling and woodworking to the utilization of sawdust and wood-chips for fuel and other purposes. Many of the problems raised in wood-cutting were of somewhat complex nature and needed both time and special treatment to provide solutions. Over two hundred and fifty technical enquiries were dealt with during the year and advice was sought by one hundred and fourteen visitors.

WOOD PRESERVATION

Testing of Wood Preservatives

When wood preservatives are tested by field service tests they are usually tested at one arbitrary concentration so that little is known of the effect on the life of treated timber of varying concentrations of preservatives. Such information is becoming necessary since it is now common practice in commercial treatments with water-borne preservatives to alter the concentration of the treating solution with the permeability of the wood being impregnated. The performance of a wood preservative over a wide range of concentrations is also needed to obtain a full appreciation of its value. A new series of tests has therefore been started to obtain data on the efficiency of wood preservatives over a range of concentration from well below to well above those used in practice. Two permeable timbers which can be completely impregnated to give homogeneous test material are being used for these tests, which are being carried out at two sites, one at the Laboratory and the other at Thetford in Norfolk. It is intended to test the more important preservatives by this method and during the past year two water-soluble type preservatives have been put under test.

Railway Sleepers

Service trials with railway sleepers at a number of sites in the main line tracks of British Railways have now been in progress for 15 years and a complete inspection has been made during the year. This experiment has three main objects, namely, to find the most effective process for creosoting sleepers, to determine the main causes of deterioration of sleepers in the track and to ascertain the suitability of certain home-grown timbers for sleepers. The indications so far are that all the methods of creosoting tested have been adequate for preserving the sleepers against fungal decay in their present

conditions and that their ultimate life will be determined by mechanical breakdown and not by decay. Some sleepers have already been removed from the track because of mechanical breakdown.

The mechanical defects that develop in service include bad splitting, chair cutting and gauge spreading, and if any improvement in the life of sleepers is to be obtained ways must be found for reducing the incidence of these defects. The experiments have shown that heavy splitting, which is a prominent cause of failure, can be greatly reduced by incising. It is clear also that any improvement in the preservation of sleepers will involve the use of a preservative that in addition to preventing decay also affords protection against weathering and mechanical degrade. Experience in other countries where splitting is even worse than in this country has indicated that wood preservatives having good water-repellent properties afford the best protection against this kind of failure. Factors such as the method of fixing the rails to the sleepers and the way of laying the sleepers, i.e. whether heart face up or down, are also believed to have an important bearing on their mechanical life.

The tests show that there appears to be little, if any, difference as yet between the performance of home-grown Scots pine and Douglas fir and the imported Baltic redwood, which has been the standard sleeper wood in this country for many years.

Electricity Transmission Poles

One of the main problems since the war has been raised by the incidence of premature decay in a large number of redwood poles creosoted in the early 1930's. Many such poles have been examined and it has been established that they have invariably failed through internal decay of untreated sapwood. This would not have occurred in properly creosoted poles in which the sapwood is always completely penetrated. At the time these poles were creosoted there was an unusually heavy demand and it is almost certain that many of them were creosoted either green or without sufficient seasoning and that this has been the main cause of their unsatisfactory performance. Unfortunately these failures are occurring at a time when poles are very costly and difficult to replace, and several treatments of the poles *in situ* have been suggested for prolonging their useful life. In the past there has been no demand in this country for remedial treatments of this kind so that it is not known whether or not they are effective. At the request of the Electrical Research Association tests have been undertaken to study those remedial processes that are to be put on trial.

Pressure Impregnation of Timber

Work has continued on the investigation of the main factors affecting the penetration of wood by liquids. The technique of using small closely matched samples has been perfected and a method of accurately measuring small and irregular penetrations of preservative has been developed. Studies have been made on the effect of varying oil temperatures and pressures on the amount of oil injected into wood.

Standard impregnation tests by pressure and open-tank methods have been carried out on a number of new timbers to obtain information on their ability to absorb preservatives.

Permeability of Wood

A method has been developed for measuring the flow of air through wood in both lateral and longitudinal directions for investigating the permeability of wood and the factors influencing it. The advantage of using air for this purpose is that measurements of permeability can be made without materially affecting the wood as occurs when liquids are used. This method has so far been applied to compare the permeability of a large number of species and to find how the permeability of a softwood varies with varying moisture content.

Properties of Charcoal

During work on the ignition properties of charcoal the effect of the presence of some metallic oxides and alkali metal carbonates has been studied. It has been found that these substances lower the ignition temperature of charcoal, often to a marked degree, and that this effect varies with the temperature at which the charcoal was originally produced.

Note on American Practice

The Officer in Charge of the Section made a tour extending over three months in the U.S.A. and Canada under the auspices of the Economic Co-operation Administration to study the wood preservation industries in these countries. The tour proved both instructive and interesting and afforded an opportunity for valuable discussions with leading members of the American industry, which is a large and progressive one. Visits were made to technical institutions and to a large number of commercial and railway treating plants.

A full report is in preparation, but the following impressions may be of interest:

The wood-preserving industry in North America is a very extensive one of comparatively recent development and it is not surprising therefore that, in general, the wood-preserving plants are more modern and efficient than those in this country and have usually been designed by specialists with a wide knowledge of wood preservation. Plants are also specially designed for the class of material being handled. Cylinders are efficiently insulated allowing high temperatures to be used economically, and this results in better and cleaner creosote treatments.

Treating yards are well laid out and extensive use is made of mechanical handling and processing equipment. Much attention is paid to accurate plant control. A well equipped laboratory is regarded as essential and the treating plants are under the charge of university-trained technical staff. Practically all preservative treatments are carried out to appropriate specifications issued by such organizations as the American Wood-Preservers' Association, the American Railroads Engineering Association and the U.S. Government. Treatments and products are generally inspected. The American Standard Specifications require the use of oil preservatives for all timber used in contact with the ground where the maximum life is required. Transmission poles and piling are pressure-creosoted though limited treatments of poles and cross-arms have been made with solutions of pentachlorophenol in petroleum oil. Railway sleepers are now all treated with creosote or mixtures of creosote with coal tar or petroleum fuel oil as these have proved the most effective preservatives. Creosote-coal-tar mixtures are becoming increasingly used as it is considered

that this mixture affords better protection against mechanical degrade and splitting.

Marine piling is always used in the round and is pressure-creosoted with complete penetration of the sapwood. This has a great advantage over squared piling in that the sapwood which can be readily impregnated is retained and gives a deep band of heavily preserved timber. This form of piling could with advantage be adopted in this country although it would mean a break with tradition.

Water-soluble preservatives are used for the preservation of timber used out of contact with the ground but which may be liable to decay or insect attack such as in building and waggon timbers.

Pressure treatments are carried out to a high standard, and with refractory timbers such as Douglas fir long treatments are often employed even with incised material as it is recognized that they are necessary to obtain satisfactory protection.

Advisory Work in Wood Preservation

Many enquiries have been received during the year as to the suitability of various timbers now being newly imported as substitutes for traditional timbers for a variety of purposes. The shortage of softwoods has been largely responsible for the general interest in these new timbers which are being used on an increasing scale for such purposes as horticultural work, building, body work, boat building and a variety of joinery purposes. In many of these uses wood is exposed to conditions conducive to decay and many requests have been received for information on the durability and preservative treatment of these new timbers. For many of them, such little information as is available is being supplemented as quickly as possible to deal with the enquiries.

Another enquiry often received concerns the relative merits of painting as against preservative treatment and it is clear that there is commonly some confusion on this subject. The function of a paint, varnish, or other film-forming material, in addition to improving the appearance, is to protect the timber against weathering and to act as a water repellent. Except in so far as these finishes keep the timber dry they are not wood preservatives in the usual sense of the term. Wood preservatives are toxic to insects, fungi, marine borers, etc., which can attack and destroy wood and their purpose is to prevent such forms of attack. In general they are not to be regarded as alternatives to paint as they do not afford protection against weathering.

The number of wood preservation enquiries answered by letter during the year was 380.

MYCOLOGY

General

Additions to the herbarium collection of wood-rotting fungi have come from Austria, India, Ceylon, and the Argentine. During this year there was little time available for field work in this country, but the opportunity was taken during a visit to Sweden to collect fungi there.

Colour photography is being used to record the appearance of various decays and stains in timber and of cultures which show characteristic colours, and a collection of Kodak Ektachrome transparencies is being built up. These

can now be obtained in sizes up to 10 × 8 in., and provide excellent display material for exhibition and demonstration work.

The collection of cultures of wood-inhabiting fungi has been maintained and enlarged by the receipt from Dr. Nobles of the Central Experimental Farm, Ottawa, of a considerable number of cultures of fungi which attack Canadian timbers.

A note on the occurrence of *Trametes hispida* in England and its cultural characteristics has been prepared and is in the press[1]. A similar study of *Polyporus quercinus*, a rare fungus found on beech in Blenheim Park in 1949, is also being prepared for publication.

Remarkably long rhizomorphs of *Armillaria mellea* were received from a waterworks, where they had been found floating in the water in a tunnel. A note describing them and their rate of growth has been prepared for publication[2].

Dry Rot in Buildings

Dry rot continues to be very prevalent, particularly in certain areas, and in large country properties whose upkeep has been neglected over a period of years.

In conjunction with the Building Research Station, work has continued upon the development of antiseptic plasters for treatment of walls infected with *Merulius lacrymans*. Further tests have shown that the cuprous oxide/magnesium oxychloride cement is not so effective for practical purposes as renderings based on zinc oxychloride. Improved methods of testing the effectiveness of these plasters are being studied.

In addition to those species well known as the cause of decay in timber in buildings, there is a number of fungi which are occasionally found growing on woodwork in houses, and a note describing the more important and interesting of these has been prepared for publication[3].

On three occasions decay of softwood joists has been found to have been caused by *Fomes roseus*, which is a rare fungus in this country and which may be supposed to have been present in the wood when it was imported.

Deterioration of Timber in Water-cooling Towers

As explained in the last Report, the breakdown of timber in water-cooling towers is of an entirely different type from that brought about by normal wood-rotting fungi, but examples of decay similar to that which occurs in the louvres of cooling towers can be found in other situations and the following examples have been observed. In all of these, microscopic examination showed perforations of the secondary cell walls, particularly in the summerwood, caused by hyphae running longitudinally within the thickness of the cell walls.

Scots pine ..	A joist from the sub-floor of a house subject to flooding.
	A pressure-creosoted pile from the River Nene.
Yew	Bog yew from Norfolk.

[1] CARTWRIGHT, K. ST. G. A Note on the Occurrence of *Trametes hispida* in England and its Cultural Characteristics. *Trans. Brit. mycol. Soc.*, 1950, **33**, 332–334.

[2] FINDLAY, W. P. K. The Development of *Armillaria mellea* Rhizomorphs in a Water Tunnel. *Trans. Brit. mycol. Soc.* (*In the press.*)

[3] FINDLAY, W. P. K. A Note on the Fungi of Less Common Occurrence in Houses. *Trans. Brit. mycol. Soc.*, 1950, **34**, 35–37.

English oak .. Structural timber from a building.

Beech .. .. { Planks buried in a garden. / Buried creosoted plywood.

Krabak .. Timber from Siam showing breakdown when imported.

Further photomicrographs illustrating this type of breakdown have been prepared.

The conditions under which *Chaetomium globosum*, a cellulose-destroying fungus, can grow and cause decomposition of wood have been studied, and breakdown similar to that observed in cooling towers has been obtained in samples of beech kept in contact with nutrient agar.

A paper describing work carried out to date on the breakdown of timber in water-cooling towers is being prepared for publication.

Decay of Timber in Boats

Following upon the inspection last year of a number of wooden naval craft, a paper, with a foreword by the Director of Naval Construction, on the decay of ships' woodwork has been prepared for publication.

Physiology of Wood-destroying Fungi

The experiment on the survival of wood-rotting fungi in dry wood continues and living cultures of *Lenzites sepiaria* and *L. trabea* have been obtained from blocks of wood which have been stored for six years at 45 per cent relative humidity. A paper describing the results so far obtained has been published[1]. As this experiment was carried out at a temperature somewhat above the optimum for the growth of *Merulius lacrymans*, it is being repeated with this fungus at a lower temperature.

Dr. Birkinshaw at the London School of Hygiene and Tropical Medicine has continued to co-operate with the Laboratory and has completed his study of the volatile substances produced by *Endoconidiophora* spp. in culture and has shown that isobutyl acetate, methyl heptenone and methyl heptenol are responsible for the odours produced[2]. A paper on the metabolic products of *Polyporus benzoinus* will shortly be published.

Sap-stain Investigations

Isolation of fungi from imported timber showing sap-stain continues. Time has not permitted a sufficiently detailed study to allow of precise naming of all the isolations.

Certain of these fungi (and others received for identification) are not readily identifiable as they produce only sterile mycelium in malt agar culture. Further methods of obtaining fructifications by growing the fungi on natural media are being employed.

Laboratory Tests on Resistance of Timbers to Decay

Standard laboratory tests have been carried out on the following timbers to determine their resistance to fungal decay: albizzia, antiaris, berlinia, dahoma,

[1] FINDLAY, W. P. K. The Resistance of Wood-rotting Fungi to Desiccation. *Forestry*, 1950, **23** (2), 112–115.

[2] BIRKINSHAW, J. H., and MORGAN, E. N. Biochemistry of the Wood-rotting Fungi. 6. Volatile Metabolic Products of Species of *Endoconidiophora*. *Biochem. J.*, 1950, **47** (1), 55–59.

makoré, mjombo, mjembe, mgongo, muhimbi, nyankom, ogea, pterygota, and yellow sterculia; of these, albizzia, makoré and mjembe prove to be the most resistant to decay. Tests on binuang, Burma teak, rauli and utile are in progress.

Laboratory Tests of Wall Boards

The decay resistance of a number of wall boards, some of them specially treated against fungal attack, has been tested in the Laboratory. The draft of a standard method for laboratory testing of decay resistance of wall boards has been submitted to the relevant Committee of the British Standards Institution.

Laboratory Tests of Wood Preservatives

Laboratory tests of the toxicity of a further number of proprietary wood preservatives have been carried out at the request of their manufacturers. Some of these products are new formulations of well known products whose performance the manufacturers wish still further to improve, or which contain materials in short supply which it may be necessary to replace.

Mycological Technique

Conservation of Cultures. A recently described method for conserving living cultures over periods of several years is being tried. The method consists in covering ordinary cultures on agar slopes to a depth of one cm. with sterilized heavy mineral oil (medicinal paraffin). The cultures under oil cannot dry out and there is no risk of their becoming infected with mites carrying spores of moulds and other contaminants. Cultures conserved in this way are reported to have remained alive without loss of vigour for periods up to 5 years and more. Duplicate collections on ordinary malt agar are also being maintained for day-to-day use, and the set maintained under oil will be regarded as a reserve in the event of accidental loss of any of the other cultures.

There is a regular demand from firms and from teaching establishments for cultures. A large number has also been sent to other research laboratories in Ottawa, Melbourne, India and Portugal.

Use of Soil as a Medium. The use of soil instead of agar as a medium on which to grow the test fungi has been studied further and a soil suitable for the growth of wood-rotting fungi has been obtained from Kennington Nursery, near Oxford. Vermiculite, to which reference was made in the last Report, has not proved to be so good a medium as agar or soil, even when apparently adequate amounts of nutrients are added to it.

Penetration of Preservative in Test Pieces. Complete penetration is necessary to obtain even distribution of the toxic material within test pieces for laboratory work. Experiments to compare impregnation of test pieces cut to expose more or less end-grain have been completed, and it has been found that, using pine sapwood and beech, there appears to be no appreciable improvement in absorption during 10 minutes treatment by using pieces with the grain running across the short axis instead of parallel to the long axis of the standard size blocks, but that using spruce, improved absorptions are obtained in the cross-grained blocks.

Advisory Work in Mycology

The number of enquiries dealt with by letter again shows an increase over the figure for the previous year, and amounted to a total of 933. Decay of timber in buildings still remains the subject of most of the enquiries and it was necessary to undertake 18 visits of inspection to affected property. Most of these inspections were carried out on behalf of other government departments and local authorities, or were to buildings of national importance or historical interest.

An inspection was made of a number of prefabricated Canadian timber houses constructed with Douglas fir carcassing which had been stored in air-tight sheds for 12–18 months, during which time severe decay had developed in the Douglas fir. It was found that the timber had been insufficiently seasoned before the components had been tightly bundled up and that, owing to the conditions of storage, no drying had been possible and so extensive rot caused by *Poria* sp. and *Coniophora cerebella* had occurred. Staining and deterioration in shipments of imported timber and decay of woodwork in boats were also the subject of many enquiries.

There has been a good deal of further interest in the possibility of composting sawdust to provide a humic material for addition to soil, and enquirers have been referred to available sources of information.

Among enquiries of interest, the following may be quoted: methods for preventing decay in large piles of pulpwood; the cause of stain in maple rollers for mangles, and in zapatero (Venezuelan boxwood) for brush backs; decay in chestnut timbers of a shooting brake; the cause of rapid decay in reed thatching; and the identification of a giant puff-ball found under the floor of a church.

CHEMISTRY

Research on Wood Analysis

It has been possible during the year to devote more attention to fundamental work on wood analysis and an investigation on certain aspects of the determination of holocellulose has been started. The term "holocellulose" was originally intended to describe the total polysaccharide fraction of the wood cell wall. It has been established by researches carried out in Germany, the United States and elsewhere over the past 15 to 20 years that, by the use of relatively mild treatments, wood can be delignified so as to yield an end-product consisting substantially of polysaccharides and representing a much higher percentage of the weight of original wood substance than the cellulose as determined by the time-honoured procedure of Cross and Bevan. In this modern work, delignification has been effected by repeated treatments of wood with chlorine dioxide and/or chlorine followed by extraction with alcoholic solutions of organic bases instead of the aqueous solutions of inorganic bases used in the past. The advent of sodium chlorite in commercial quantities has also led to the use of this chemical as a delignifying agent since, under acid conditions, it gives rise to chlorine dioxide. In the presence of a suitable buffer to control pH, sodium chlorite can be used without subsequent extraction with an alkali to effect virtually complete delignification of wood.

Complete delignification of wood apparently cannot be achieved by any of the procedures described above without bringing about, at the same time, some

degradation and even loss of polysaccharides. Maximal yields of polysaccharide have been obtained when a small proportion of lignin is left in the residue. It has thus become customary to determine this residual lignin analytically and, after making an appropriate deduction, to record results for holocellulose, lignin-free. It has been observed in this and other laboratories, however, that the sum of the lignin-free holocellulose content and the lignin content* of a wood frequently amounts to over 100 per cent of the dry weight of the original wood. The significance of this "overlap", which may amount to from 5 to 10 per cent by weight of original oven-dry wood of some samples, has so far not been adequately explained. It has been suggested that the lignin determination itself is suspect and that the residue described as lignin after treatment of wood with acid may contain, in addition to the true lignin, a proportion, represented substantially by the overlap, of material resulting from the action of 72 per cent sulphuric acid on wood carbohydrates. Alternatively, it has been suggested that the so-called holocellulose contains undetermined, modified lignin in addition to the small proportion of residual lignin which is amenable to determination by the 72 per cent sulphuric acid method. Present indications are that the latter suggestion is more nearly correct. In an extensive series of orientating experiments using beech and spruce woods and buffered solutions of sodium chlorite at different temperatures, it has been established here that, under carefully controlled conditions, the overlap referred to earlier in this paragraph is present throughout delignification but rises to a maximum before declining to a very small proportion of the original wood towards the end of the delignification. This suggests, in conjunction with other observations, that at least two phases or stages are involved in the delignification of wood by buffered sodium chlorite. In the course of the reaction or reactions, two modifications of lignin are formed. One modification is soluble in the buffered chlorite solution and is thereby removed from the wood. The other modification is insoluble in the buffered chlorite solution and is therefore retained in the holocellulose residue along with any unmodified lignin which may remain. This second modification of lignin is, however, soluble in the sulphuric acid used in the conventional lignin determination. The results obtained so far suggest that, under the prolonged action of chlorine dioxide at 50°C., the acid-soluble modification of lignin is transformed into the other modification which is soluble in buffered chlorite solution.

Additional evidence concerning the chemical modification of lignin by buffered sodium chlorite is derived from the colour of the lignin obtained from the wood residue at various stages of delignification. Sulphuric acid lignin obtained from normal, untreated wood has a characteristic chocolate-brown colour and is generally assumed to be of high molecular weight (in excess of 5,000). It has been observed that the lignin remaining in wood after treatment with buffered sodium chlorite has the normal colour at each stage of delignification up to the stage of maximum overlap already described. At and after this stage, the lignin residue, which is, of course, a steadily diminishing quantity, is of pale buff colour reminiscent of the low molecular weight (under 5,000) lignins which have been described in the literature. Further and more detailed investigation of the mechanism of delignification by buffered sodium chlorite is in progress.

* As determined by the 72 per cent sulphuric acid method.

Chemical Examination of Secondary Colonial Timbers

Further work on the sapogenin obtained on hydrolysis of the saponin of morabukea[1] has confirmed its identity as oleanolic acid, a triterpene known to occur in combination in other saponins. The preparation of 200 grams of oleanolic acid was undertaken for the National Insitute of Medical Research, using Morabukea heartwood as a source. The overall yields of saponin and of oleanolic acid were 4·3 per cent and 0·78 per cent by weight of oven-dry, original wood respectively.

Information obtained from a trade source indicates that the yield of saponin from the heartwood of either morabukea or mora is very low compared with the yield obtained from current commercial sources of saponin powder. It would therefore appear that production of saponin from these woods might not be commercially feasible unless a profitable outlet could be found for the fibrous wood residue remaining after extraction. In an endeavour to meet problems of this sort, the Laboratory has drawn up, on behalf of the Colonial Products Research Council, a programme of experimental work whereby the suitability of secondary Colonial timbers for the production of fibreboards will be assessed. The principal items of equipment for making fibreboard on a laboratory scale have now been installed and a limited amount of exploratory experimental work has been carried out.

Lapachonone from Peroba de Campos Wood (Paratecoma peroba)

The further investigation of this substance, which was discussed in the 1949 Report[2], has been continued at the University of Manchester under the direction of Professor E. R. H. Jones, F.R.S. Apart from confirming that lapachonone and *iso*-lapachonone each contains one methoxyl group, no further constitutional work on these substances has been carried out at this Laboratory. Twenty-five grams of pure lapachonone have been prepared and supplied to Professor Jones.

Crystalline Deposit in Iroko Wood (Chlorophora excelsa)

Natural fissures in this wood are frequently found to contain calcareous concretions formed as a result of evaporation of water from the tree sap. In a sample of the wood received from a commercial source there occurred a colourless crystalline deposit which was superimposed upon the more usual calcareous type of deposit. The new deposit proved to be the calcium salt of an organic acid and the latter was identified by its reactions, and by partition chromatography on paper, as malic acid. The crystalline substance proved, on quantitative analysis, to be a hydrate of calcium malate. It is considered probable that, in common with the more usual inorganic deposit, calcium malate is deposited as a result of slow evaporation of water from sap which has seeped into cavities in the growing tree. Malic acid is a common component of tree sap. A short paper[3] describing this calcium malate deposit has been accepted for publication.

The Extractives of ' Rhodesian Teak ' (Baikiaea plurijuga)

Although ' Rhodesian teak ' is known to be extremely resistant towards fungal decay there is some doubt about the identity of the toxic principle in

[1] Forest Products Research 1949, p. 35. (H.M.S.O., *in the press.*)

[2] Forest Products Research 1949, p. 37. (H.M.S.O., *in the press.*)

[3] FARMER, R. H., and CAMPBELL, W. G. The Composition and Origin of a Crystalline Deposit in Iroko Wood (*Chlorophora excelsa* Benth. and Hook f.). *Emp. For. Rev.*, 1951, **30** (1), 64–65.

this wood. The wood contains some 17 to 20 per cent of extractives of which tannins and phlobaphenes comprise the greater part. A water-soluble crystalline nitrogenous substance is also present among the extractives and this has been isolated in 0·7 per cent yield (based on oven-dry original wood). The analytical data obtained for this substance are in substantial agreement with those previously obtained by Professor F. E. King et al[1] of Nottingham University, who claim that it is a hitherto unknown amino acid and name it "baikiain". Preliminary tests have indicated that, after isolation, the water- or alcohol-soluble extractives of ' Rhodesian teak ' are not appreciably toxic towards wood-destroying fungi cultures in agar media. Toxicity tests involving other media are in progress.

The commercial possibilities of the tannin of ' Rhodesian teak ' with respect to the leather industry were examined some 18 years ago[2] when it was found that an extract containing 65 per cent of tannin yielded leather of satisfactory quality in every respect except colour. The leather produced had a strong reddish colour and attempts at that time to decolorize the wood extract failed. On extraction with acetone, the wood used in the current investigations yielded 8·6 per cent of tannin and 9·3 per cent of dark red phlobaphene. The phlobaphene fraction was precipitated by pouring the concentrated extract into twice its volume of water and the tannin fraction was recovered from the liquor, after filtration, by extraction with ethyl acetate. On evaporation of the solvent, the tannin fraction was obtained as a pale reddish-brown powder which, on analysis by the hide powder method, was found to contain 77·7 per cent of tannin and 5·5 per cent of soluble non-tannin. Supplies of a few pounds of tannin and phlobaphenes were prepared for further investigation.

Substitute Timbers in the Chemical Industry

The demand for timbers to replace traditional species now in restricted supply, and particularly the well-known softwoods of North American origin, is nowhere more apparent than in the chemical industry where timber is an important material of construction for plant, floors, platforms, roofing, etc. For these purposes pitch pine, southern cypress, Douglas fir and Californian redwood have found favour in the past and adequate substitutes for them have been difficult and, in some circumstances, impossible to find.

In this connexion two members of the Chemistry Section attended the Conference arranged at Birmingham by the Society of Chemical Industry on Materials of Construction in the Chemical Industry. An exhibit was prepared for this Conference of samples of traditional vat-making timbers together with suggested substitutes selected from lesser-known timbers, and a paper was presented to the Conference on the use of timber in the Chemical Industry. A valuable discussion was thereby evoked from which it was elicited that members of the Industry had formed a good impression of such timbers as doussié, locust, ekki, pyinkado, greenheart and purpleheart when used in plant construction. Ekki was cited as being very good for very severe duties involving contact with hot acid and one firm cited purpleheart as " the most generally satisfactory all-round wood so far encountered " for use in contact with

[1] KING, F. E., KING, T. J., and WARWICK, A. J. The Chemistry of Extractives from Hardwoods. Part III. Baikiain, An Amino Acid Present in *Baikiaea plurijuga*. *J. Chem. Soc., Lond.*, 1951. (*In the press.*)

[2] FURLONG, J. R. *J. Intern. Soc. Leather Tr. Chem.*, 1932, **16**, 237.

solutions containing such chemicals as acids, alkalis and oxidising agents. The paper[1] and the discussion which followed it have been published in full.

The resistance of specific woods to the action of chemicals such as dilute solutions of non-oxidising acids is difficult to assess by laboratory tests. In vat work, for example, it is well known that skill in fabrication is at least as important as the choice of timber. Timbers nevertheless do vary in their intrinsic resistance to acids and this has been shown[2] to depend on such constitutional factors as (1) a high α-cellulose content, (2) a high lignin content, and (3) a low pentosan content. By analysing a given wood, adding the percentage α-cellulose and lignin contents and subtracting the total pentosan content from this sum, a numerical index of intrinsic acid-resistance is obtained. Such an index can, however, only be a rough guide to the selection of woods for vat construction since other factors such as bulk density, permeability to liquids, straightness of grain, natural durability towards fungal decay, the proportion and nature of minor components, shrinking and swelling characteristics, etc., have also to be taken into account.

The Use of Wood in Association with Metals

Enquiries continue to be received on the corrosion of metals in wood/metal assemblies such as occur in boats, automobile bodies, metal-faced cabinets, etc. Aluminium and its alloys have figured prominently among the 30 dealt with in the course of the year. Few if any woods induce specific chemical attack on aluminium but it is frequently overlooked that, when in a moist condition, all woods acquire the properties of electrolytes. From observations made in the Laboratory over a period of years it has been established that moist wood is also a somewhat complex buffer system, the pH of which varies from approximately 3·0 to approximately 10·3 according to species. It is known that aluminium and some of its alloys corrode at all pH's although the rate of corrosion is minimal between pH 5·0 and pH 7·0. When the wood of a composite structure including aluminium is relatively dry, corrosion of the metal will be slight or non-existent. The risk of corrosion occurs when the wood acquires a moisture content in excess of approximately 18 to 20 per cent. For such wet conditions selection of woods according to the pH which they engender provides one but by no means the best method of retarding corrosion. Where aluminium is concerned, it is important to note that corrosion can be accelerated by factors other than pH as such. For example, differences in pressure at various parts of the metal surface in contact with a porous material like wood have been suspected of causing corrosion of the pitting type. Since aluminium happens to be anodic to several other common metals it is very liable to corrosion by galvanic action when incorporated in composite structures involving wood and other metals. The attachment of aluminium to wood by steel or brass screws can thus be a cause of serious corrosion of the aluminium in structures exposed to the weather or to damp conditions indoors.

The general conditions governing the use of aluminium and its alloys in association with timber have been discussed with technical representatives of

[1] CAMPBELL, W. G., and PACKMAN, D. F. The Use of Timber in the Chemical Industry. (Materials of Construction in the Chemical Industry, pp. 49–53.) London, Society of Chemical Industry (1950).

[2] CAMPBELL, W. G., and BAMFORD, K. F. Factors Affecting the Relative Resistance of Certain Woods to Hydrolysis by Dilute Sulphuric Acid. *J. Soc. chem. Ind., Lond.*, 1939, **58**, 180–185.

the Aluminium Development Corporation and other interested bodies, and it is hoped that joint investigations may result in improved practices in industry. For the time being, the following general recommendations concerning wood/aluminium assemblies have evolved from observations in the Laboratory:

(1) The wood should be well-seasoned before assembly and kept as dry as possible during service.

(2) Where wetting of the wood during service is probable, it would be advisable to coat with bitumen, or other electrically neutral barrier, all metal parts which are to be in direct contact with wood.

(3) Woods which under moist conditions engender a pH substantially less than 5·0 or over 7·0 should be avoided unless dry conditions during service are assured.

(4) Composite structures involving wood and aluminium should be designed to avoid bi-metallic action.

Chemical Effects of Weathering on Wood in Normal and Polluted Atmospheres

It has been known for many years that the development of the grey, silky lustre acquired by wood exposed to the weather is promoted by sunlight and moisture. Weathering, as such, is a surface action penetrating to depths of the order of 0·01 inch and its effects are, therefore, most severe from an economic standpoint in sheet materials such as the face veneers of plywood where the ratio of surface area to volume of individual pieces of wood is greatest. Radiation in the visible part of the spectrum causes woods like spruce, birch and poplar to develop a brown colour and catalyses the atmospheric oxidation of cellulose[1]. In some circumstances marked degradation of lignin may accompany the oxidation of cellulose so that, in the exposed layers of wood, the cells tend to separate from one another, and their wood substance is embrittled. The brown reaction products of the photochemical oxidation of wood are soluble in water so that the leaching action of rain removes them and tends to leave a very thin, and relatively loose layer of almost white, brittle cellulose material on exposed wood surfaces. This, superimposed upon the underlying normal wood, probably accounts for the optical effect perceived as the grey, silky lustre. In course of time, the abrasive action of wind and rain removes the brittle surface layer from weathered wood and exposes fresh surfaces to attack. Exposure of wood to ultra-violet radiation frequently causes bleaching in addition to oxidative degradation.

Thermal radiation over prolonged periods causes hydrolytic degradation of wood, especially under moist conditions. Cellulose is the principal wood component affected here and the resultant shortening of its chain molecules is reflected in depreciation of the mechanical strength of the wood as a whole in much the same way as wood is weakened by fungal attack of the brown rot type. An interesting example of thermal decomposition was encountered during the year in Scots pine roofing timbers of a railway locomotive shed which had been in use for upwards of 20 years. From a chemical examination of borings taken from timbers of cross sections up to 10 × 6 in., it was established that, on the average, hydrolysis had taken place to a depth beneath the surface of at least two inches and was relatively severe throughout the first half-inch of depth. Rough estimates based on the known relationship between

[1] RICHTER, G. A. Relative Permanence of Papers Exposed to Sunlight. *Industr. Engng. Chem.* (Industr. Edn.) 1935, **27**, 432–439.

degree of hydrolysis and decrease in the modulus of rupture of wood indicated that whereas, on the average, the roofing timbers in question might have lost up to 50 per cent of their strength, the strength loss might have been anything up to 80 per cent in cases of severe degradation. Structures made of wood in this condition may well be unsafe. Since it is known that dry wood is much more resistant to thermal decomposition of the type indicated than wet wood, the best way of minimising similar damage to new woodwork would be to coat it immediately after assembly with a heat-resisting, impervious paint.

The chemical effects of normal weathering described above are frequently accelerated by polluted atmospheres in large cities and chemical plants. Traces of sulphur dioxide, acting either alone or in association with ammonia over prolonged periods at ordinary atmospheric temperatures, induce a peculiar effect on wood. Exposed surfaces gradually acquire a woolly appearance and tufts of fibres are easily flaked or rubbed off. The condition was first observed at the Laboratory some years ago in samples taken from the structural timbers of oast houses which had been exposed to the sulphurous fumes from coke fires. The samples had retained detectable amounts of sulphur and ammonia as acid ammonium sulphate and the superficial woolliness was accounted for by the delignifying action of acid ammonium sulphite. Since most of the lignin in wood normally occurs in the middle lamellar regions of the cell walls, chemical degradation or removal of lignin results in separation of the cells (defibration). Under some circumstances the action of sulphurous fumes is progressive and can lead to serious deterioration in the strength properties of timbers. Since this condition was originally diagnosed, many examples of it, including some during the year under review, have formed the subject of enquiries. In most examples examined the suspected causal agents have been improperly vented coke fires, gas cookers or gas lighting installations.

Advisory Work in Chemistry

The advisory work has been referred to on page 5 of this Report.

ENTOMOLOGY

Investigations on Lyctus *Powder-post Beetles*

D.D.T. Spray Treatments. Attention has been drawn in the last two reports to the experimental work leading up to the Laboratory's recommendation of the use of a D.D.T. spray for the prevention of infestation by *Lyctus* in sawn timber during seasoning or storage. Detailed examination of sawn logs of English oak treated in 1948 has now been completed and the first results confirmed. A thorough spray treatment in the early spring of all sapwood with D.D.T. at a concentration of 2 per cent, made up with water from a miscible oil concentrate, will prevent infestation by *Lyctus brunneus* at least throughout the rest of the year. A similar type of formulation at a concentration of 1 per cent has given good results but failed to give complete protection; applied at a concentration of 0·5 per cent infestation took place, but was considerably less than in untreated controls. A large degree of protection was afforded when the D.D.T. was applied in the form of a suspension in water, made up from a commercially available wettable powder at a concentration of 2 per cent, but the results were not so reliable as with the oil-based formulations.

Tests with Insecticidal Fogs. Evaluation has now been completed of the results of treatment in the spring of 1949 of two piles of English oak (T and T

1½-inch boards) with an insecticidal mist or fog using, respectively, 5 per cent D.D.T. made up as an emulsion in water from a miscible-oil concentrate and 1 per cent gamma isomer of benzene hexachloride prepared from the water-dispersible Gammexane dust P.520. First results had shown in 1949 that beetles of *Lyctus brunneus* in contact for 24 hours with test samples removed from the piles some ten weeks after treatment were not obviously affected and when placed subsequently on untreated oak sapwood laid eggs from which larvae developed normally. Even at that time it was apparent that neither insecticide, applied as a fog at the concentrations used, was likely to prevent attack by *Lyctus* in commercial size stacks of hardwoods. The condition of selected boards withdrawn in 1949 from treated and untreated piles and then exposed to controlled infestation, together with the condition of the remainder of the piles when dismantled in the autumn of 1950 after exposure to natural infestation by the insect, has confirmed that attack was not prevented, although partial protection had been achieved. As the piles were taken down, each board was examined superficially for the presence of bore dust and/or exit holes. In the D.D.T.-treated pile 30 per cent, and in the Gammexane pile 39 per cent of the boards showed signs of infestation, as compared with 88 per cent in an untreated control pile. Although sapwood, which alone is susceptible to attack by *Lyctus*, was present at least along one edge of each board, its amount, distribution, and suitability for attack, as determined by its starch content, could not be accurately controlled from the material available for the experiment. It is thus probable that the above figures do not represent a true measure of the full extent of infestation by the insect in the piles. Data on the distribution of attack within the treated piles showed, as might be expected, that boards nearest the direction of application of the insecticidal fog received most protection, attack being heavier in the centre and on the far side of the piles.

In general these results, together with those of an earlier experiment on the premises of a London timber merchant, indicate that neither D.D.T. nor Gammexane, applied in the form of a fog at the concentrations stated, are effective alternatives to spray treatments with the same insecticides, even at lower concentrations. Applied in such a way, the distribution of the insecticidal deposit throughout a pile of timber is insufficient to prevent egg-laying by *Lyctus brunneus* in all sapwood surfaces, even within a few weeks of treatment.

Laboratory Tests with Pentachlorphenol Preparations. In view of the increasing use of pentachlorphenol in other countries for the prevention and control of damage by wood-boring insects, a series of tests with four proprietary preparations based on this preservative has been started to determine their value when applied by a one-minute dipping treatment for the prevention of attack by *Lyctus brunneus* in the sapwood of English oak. The effect on egg-laying and on larval development is being examined separately. The results of past work at the Laboratory with pentachlorphenol showed that the efficacy of such short-period dipping treatments of English oak in relation to attack by *Lyctus* is dependent upon the penetrative powers of the solvent. The results so far obtained from these recent experiments have shown that two of the four preparations tested failed to give complete protection when exposed to *Lyctus* attack one month after treatment.

Enquiries on Powder-post Beetles. The 206 enquiries on *Lyctus* and other powder-post beetles dealt with during the year represent an increase of 74

per cent over those in 1949 and are a result of the greater use of tropical hardwoods. During and immediately after the war, most *Lyctus* enquiries concerned English oak, either as rough-sawn timber or as new furniture and flooring, but within more recent years, and particularly in 1950, West African and other tropical hardwoods have become increasingly involved, mainly in the form of plywood or blockboards containing the sapwood of such susceptible timbers as obeche and afara. It has not always been possible to ascertain the complete history of affected material, but there is evidence that the trouble may start in made-up plywood or in partly manufactured blockboard, during storage either in the country of origin or in the United Kingdom.

A typical enquiry resulting from damage in manufactured timber, involving an inspection, concerned widespread attack in new laboratory bench fittings made from " off licence " hardwoods. In this instance the affected portions were sapwood of 'Tasmanian oak'. In another, advice was sought by a municipal authority on how to deal with large-scale infestation in floor blocks of 'silky oak' from East Africa, awaiting installation in a public building.

A number of enquiries concerned damage by Bostrychid powder-post beetles in such timbers as obeche, afara, bombax, usually in the form of sawn timber on arrival in this country, but occasionally as manufactured wood, for example in the cores of flush doors and in tobacco packing cases. The Laboratory was consulted by a firm of contractors in London for advice on how to deal with and prevent infestation by these powder-post beetles in structural timbers in new buildings in Dar-es-Salaam, Tanganyika.

Insect Damage in Tropical Hardwoods

The prevalence of insect damage of the pinhole borer type in many tropical hardwoods has again been of concern to timber users in the United Kingdom and the Laboratory has frequently been called upon by suppliers from many parts of the Colonial Empire for advice on preventive treatments to reduce this common defect, the full extent of which is seldom apparent in infested logs until after conversion. There still exists a strong prejudice against the use of timber showing any type of worm hole, even although it may indicate past attack no longer active in seasoned wood, and numerous enquirers have sought assurance that timber showing pinhole borer damage can be used without any risk of its increase in manufactured wood.

During the year, a further problem has arisen, of which mention has been made, in connexion with *Lyctus* powder-post beetles in plywood containing the sapwood of timbers known to be highly susceptible to attack by these pests of seasoned hardwoods. This danger is becoming more fully realized by the plywood industry and the Laboratory has been approached for assistance, including requests for experimental work, on means of dealing with this very real threat to the extended use of plywood containing such woods. The utilization for structural, as well as for joinery work of tropical hardwoods with a high proportion of sapwood, which cannot economically be discarded, entails, in the absence of any preservative treatment, a risk of infestation by wood-boring insects. In the light of experience in other countries, this cannot be dismissed as only of academic interest. The Laboratory has such problems well in mind and has taken every opportunity of bringing them to the attention of those directly concerned.

Pinhole Borers in Tropical Logs. The problem of the extensive degrade of newly felled logs of certain tropical species through fungal staining or attack by pinhole borers is still serious, since the export in a sound condition of such susceptible timbers, desirable on other grounds, is rendered difficult or impossible.

A brief account was given in the Report for 1949 of investigations which were in progress in Malaya and the Gold Coast on insecticide treatments of logs for the prevention of attack by pinhole borer beetles. The results of this work have enabled recommendations to be made for at least temporary protection, pending extraction and conversion of the timber. At the same time they have shown the need for further and more intensive work, involving the development of treatments effective against staining fungi as well as wood-boring insects, with which stain in the lighter hardwoods is often associated. Although further work is being carried out by the Forest Department in Malaya, and is yielding information of immediate value to timber interests in the Far East, investigations on the Gold Coast have unfortunately been discontinued for the present with the resignation of the officer directly concerned. The need for this work to be restarted in West Africa has become all the more apparent during the past year with the growing demand for effective prevention and remedial measures to avoid deterioration of both timber and plywood through insect and fungal attack.

During the year, considerable time has been spent in revising and bringing up-to-date the Laboratory's records of insect attack in tropical hardwoods and other timbers. The insect collections have been maintained and new material identified, as required, by the Commonwealth Institute of Entomology. A feature of interest has been the increased number of records of the presence of longhorn beetles or their larvae in timbers from the tropics.

The Common Furniture Beetle (Anobium punctatum)

Advisory Work and its Implications. This well known pest has continued to bring in more enquiries than any other single insect, some 600 requests for advice on its control being dealt with by letter and 10 inspections of infested property carried out during the year. An analysis of this work has brought out some interesting and important facts regarding its occurrence. In the first place it is significant of the status of the insect as a timber pest that notwithstanding its name, 56 per cent of these enquiries concerned infestation of structural timbers and joinery work which had been in position for a period of years, 25 per cent concerned infestation in wood from other or unspecified sources, and in only 19 per cent was furniture involved.

Accurate data are not available for the species of timber in each enquiry, but it has been abundantly evident that most hardwoods and softwoods can be attacked and are liable to severe infestation, provided that they are in a condition suitable not only for egg-laying, but also for the entry into the wood and the nutrition of the larva immediately on emerging from the egg and, later, for continued boring and growth. What these conditions of suitability are, in timbers used for building and other purposes in the United Kingdom, have yet to be more fully understood and are the object of the Laboratory's investigations on this insect.

In the meantime, it is clear that, although sapwood of most timbers is always preferred, attack may spread into the heartwood, especially where fungal

decay is present. Instances have been noted of active infestation in the heartwood of pine structural timbers which had been decayed by dry rot, and of an elm floor joist affected by a fungus of the " wet rot " type. The need for a study of the extent to which the presence of fungal hyphae of non-wood-destroyers, moulds, for instance, may render sapwood or heartwood liable to attack by the common furniture beetle has become increasingly evident from infested material examined during the year. The relations of the insect to conditions of moisture and temperature have also been shown to be of particular importance. Although the insect can live within and cause appreciable damage to comparatively dry timber and woodwork in furniture, it is frequently associated with the damp conditions found in cellars and in unventilated floors, and is particularly abundant as a pest in the wetter and milder parts of the country, e.g. in the West of England and Scotland and in Ireland.

Although no precise figures are available, these records and observations tend to support the view, widely held by competent authorities who have to deal with infestation by this insect, that within recent years it has become more widespread and is causing far more damage than hitherto. An explanation of this increase in importance may be found, in part at least, in the use during the inter-war period of poor quality softwood building timbers with a high proportion of sapwood, and of cheaper grades of plywood made up with animal glues; in the storage of furniture on infested premises during the war years, leading to its attack and subsequently its acting as a source of spread of infestation in its new environment; and in the development of fungal decay in timbers following war damage, together with delays in replacements or repairs. It has to be concluded that it is likely to continue to be a pest of increasing importance wherever the sapwood of timber, including new and unfamiliar tropical species, is utilized without any preservative treatment. Owing to the comparatively long life-cycle, which recent investigations show is probably at least three years, and because the insect does not normally attack new or recently seasoned woodwork, signs of such an increase in spread of infestation in structural timbers may not become apparent for some years.

Laboratory Investigations. One of the main problems still to be solved is the development of a suitable technique for the mass rearing of the furniture beetle, which has continued to prove a difficult species to deal with in the laboratory. Further attention has therefore been given during the year to modifications of technique to facilitate egg-laying. A satisfactory egg-laying surface has now been evolved using muslin secured mechanically to samples to be infested, thus avoiding the starch paste formerly used as an adhesive. An improved type of breeding container has also been designed.

In connexion with investigations on the susceptibility to attack of plywood made up with different types of adhesive, it is of interest to record that artificial blocks prepared from oak sapwood flour, and blood, bone, casein or hide glues, and exposed in 1947 to infestation by the common furniture beetle under laboratory conditions of temperature and humidity, gave emergence during the summer of 1950 from material containing the first two types of adhesive, but not from the others. It is probable that this limited success may have been due to the presence of preservatives in the latter two adhesives. In view of the apparent suitability of this type of medium for rearing the insect, further blocks have been exposed to attack at 22°C. and 86 per cent relative humidity, the conditions under which most of the laboratory investigations are being carried

out. At the same time work has been continued with plywood made up from Scots pine, beech and birch, with animal, casein, or synthetic resin glues.

First results, referred to in the Report for 1949, on the effect of the presence of fungal decay in timber upon the rate of larval development have been confirmed and it has also been confirmed that the weight and rate of development of larvae boring in decayed wood are markedly greater than in sound controls. These results are of especial interest in relation to the environment in which the insect has frequently been recorded.

Further material of both hardwoods and softwoods decayed by brown and white rots to a known percentage loss in weight has been exposed to infestation during the year and the work extended, in the case of oak sapwood, by impregnation of the decayed wood with peptone, yeast, and glucose, to ascertain the effect of the presence of such additional nutritive substances on the development of the larvae, as a means, it is hoped, of accelerating the breeding of the insect to provide material throughout the year for other investigations.

Attention has also been given to the pupal stage of the beetle, to the determination of secondary sex characters of use in the selection of individuals for breeding, and of the length of the pupal period out-of-doors, which has been found to be of the order of two months. A study of the nitrogen content of pupae has been started in co-operation with Chemistry Section, and it is intended to extend this work to include analysis of beetles and larvae with the object of obtaining information on the nitrogen requirements of the insect at different stages of its development.

Control. It is still the opinion of the Laboratory that the common furniture beetle cannot be used satisfactorily in this country as a test insect in investigations on insecticides and wood preservatives until its biology and food requirements are much more fully understood than at present. With existing information, test results cannot accurately be assessed. In the meantime, preventive and remedial measures against the common furniture beetle can be prescribed[1] which, if thoroughly and painstakingly applied, will go a long way towards preventing and dealing with infestation. Each case of severe damage, especially in joinery work, usually requires careful consideration of the extent to which renewal of affected timbers may be justifiable and how far treatment with liquid insecticides or, in some instances, fumigation, can be relied upon to deal with the trouble. Where sapwood cannot be eliminated in timbers used for repairs or replacement, treatment with a reputable wood preservative, preferably applied under pressure, is a wise precaution.

The Death-watch Beetle (Xestobium rufovillosum)

Work on this insect during the year has been confined to 18 inspections of infested buildings to advise on treatment. The annual inspection of the attacked timbers in H.M.S. *Victory* at Portsmouth confirmed the conclusion reached during the 1949 visit that activity is considerably less than hitherto. The number of beetles collected on the ship during the 1950 emergence period showed that, in general, the decrease recorded last year was being maintained. It was, however, considered advisable to continue the insecticide treatments and other control measures which have been in progress for some years.

[1] The Common Furniture Beetle. *Leafl. For. Prod. Res.* No. 8 (Revised 1950).

The House Longhorn Beetle (Hylotrupes bajulus)

It has not been possible to make a start on biological studies of this insect, nor of a survey of the extent of damage in areas from which it has been recorded. A further 14 occurrences have been noted by the Laboratory in the course of advisory work, and 11 of these concerned structural timbers in buildings in localities in Surrey where damage had previously been found. Two instances of the presence of the insect in imported softwood packing cases in other parts of the country were noted. The Laboratory has continued to maintain close contact with local authorities in the affected areas and with the Ministry of Health with regard to the treatment of attacked buildings and the prevention of spread of infestation. There is no evidence to suggest that the pest is of common occurrence in other parts of the country.

Investigations with D.D.T. Smokes in Buildings

The liberation of an insecticidal smoke, e.g. of D.D.T. or benzene hexachloride, for the destruction of wood-boring insects at the time of emergence, or for the prevention of infestation in buildings, offers attractive possibilities, in particular in attics, cellars, and where timbers are not easily accessible for spray treatments. An exploratory test has been carried out to investigate the value for such purposes of a D.D.T. smoke liberated from small generators marketed for domestic use. An experiment was undertaken at the Laboratory in a room of approximately 2,000 cu. ft. capacity in which samples of wood attacked by *Lyctus* powder-post beetles or by the common furniture beetle were distributed and orientated in several positions, to investigate differences in amount of deposit on the various surfaces. An estimate of the deposit obtained on the upper surface of filter papers placed horizontally at different heights above the floor showed it to be of the order of 74 mgm. per sq. ft. After treatment, observations were made upon the emergence and behaviour of beetles of both species from treated and untreated wood, and upon egg-laying and hatching.

The results have shown that such a deposit of D.D.T. did not prevent the emergence of either species from infested wood, nor did it affect the length of life of the beetles or egg-laying, if the insects were removed immediately from contact with treated surfaces. On the other hand, the length of life of both species was reduced considerably, as compared with controls, by continuous contact with treated surfaces, this effect being greatest with upper horizontal surfaces and less on vertical and lower horizontal surfaces in which in some test samples, eggs were laid by both species and hatched in due course. The conclusions from the work so far undertaken indicate that such a residual deposit of D.D.T. is insufficient to give protection against either *Lyctus* or the common furniture beetle, even within 2–7 days of treatment, except possibly on upper horizontal surfaces where it would be at its maximum. The value of the smoke for killing beetles which had emerged before or during treatment has not been determined, but is likely to be considerable.

Ultrasonics and the Sterilization of Insect-infested Wood

A series of preliminary experiments has been undertaken in co-operation with Dr. S. E. Jacobs of the Bacteriology Department, Imperial College of Science, and a radio equipment manufacturer. A 15-kc/s generator feeding a laminated nickel transducer of surface area of 6 in. by 2 in. with approximately

350 watts of ultrasonic power was used. Two-in. squares of $\frac{3}{16}$-in. birch plywood infested by the common furniture beetle were exposed for 2–4 min. with dry interface or water film at interface between sample and transducer. Subsequently, some of the samples so treated were cut up for detailed examination, whilst others were retained and emergence of insects noted throughout the summer. No immediate effect on the insects was apparent and it is doubtful whether the results so far obtained from this exploratory experiment justify its extension. The experiment suffered from the small number of insects present in the control samples, and reliable conclusions were not reached. Circumstances have prevented continuation of this work.

Advisory Work in Entomology

In addition to requests for literature, a total of 1,558 enquiries were dealt with by letter. Thirty-two inspections of property affected by wood-boring insects in various parts of the country were carried out. These figures for the entomological advisory work represent an increase of over 25 per cent on the 1949 totals, which had already surpassed all previous records. A comparatively small proportion of this increase can be attributed directly to the Department's exhibition on " Dry Rot and Woodworm " which toured the country during the second half of the year, but the greater proportion is the result of increased realization by timber suppliers, users, and householders, of the continued need at a time of shortage to prevent deterioration of timber through insect attack, whether in store or in use.

Apart from enquiries on true wood-boring insects, a common one from householders, particularly during mild damp weather in the autumn, has concerned complaints of prolonged ticking noises heard on their premises and believed to signify the presence of the death-watch beetle. The insects responsible are minute book lice (Psocids) of no importance as wood-borers but which live on moulds growing on the surface of damp wood, brick, or plaster. The ticking with which they are associated is quite distinct from the characteristic intermittent tapping of the death-watch beetle, heard only during April and May. In view of the interest shown in this type of enquiry and to dispel the confusion between the two insects, a brief note on the habits of Psocids was issued to the Press by the Department.

EXTERNAL RELATIONS SECTION

Selection and Procuring of Timbers for Testing

The receipts of timbers for the Laboratory's full general tests during 1950 included three hardwoods from Nigeria (*Sterculia oblonga*, *Berlinia* and *Pterygota*), two from the Gold Coast (*Khaya ivorensis*, the chief African mahogany, and *Mimusops* (makoré)), one from North Borneo (*Octomeles*) (binuang) and one from Sarawak (*Gonystylus*) (ramin). All of these were obtained as logs, to a volume of some 350 to 1,400 cu. ft. of each species. Most were sent by the Forest Departments concerned, with botanical material from the same trees to fix the identity. Two were got from trade stocks in the United Kingdom where the identity was reasonably certain. All these hardwoods are of actual or potential importance for export to the United Kingdom or other consumers. The quality of the logs was good and provided an adequate range and amount of material for all the required tests.

An outstanding shipment was the *Octomeles* (binuang) from North Borneo.

It was felled, cross-cut, barked, treated experimentally with one or other of three insecticides and fungicides, extracted and loaded for shipment, within three weeks, with complete notes on dates and procedure. As the timber is very perishable once it is felled, the information gained from these measures was especially useful. Another outstanding shipment was of African mahogany logs from the Gold Coast, the quality being very fine. Confirmatory tests on this premier West African wood are required, because so far only very limited tests have been done on it at Princes Risborough, and the species serves as a basis for comparison for many other woods.

A small consignment (27 cu. ft. in all) of 2½-in. planks of two difficult timbers (*Eschweilera* and *Licania*) was received from British Guiana, for special sawing and woodworking tests. These timbers present an interesting problem in that they are so full of silica and so difficult to work that they have not yet been exploited.

A small consignment of logs of nine species from the savannah forests of South East Tanganyika was accepted from the Overseas Food Corporation, for such examination and report as work on other species permitted. The logs were of small size and of the form typical of the African savannah forest, which covers great areas in Tanganyika, the Rhodesias, and elsewhere. Three of the timbers, at least, are of a useful type and of local or even emergency export value. These are *Pterocarpus angolensis* (muninga), *Afzelia quanzensis* and *Erythrophloeum africanum*, so far as the local names and an examination of the wood can identify them specifically.

The results of the tests so far completed on three other important savannah timbers of East and Central Africa, two species of *Brachystegia* (mtondo and mjombo) and one species of *Isoberlinia* (mchenga), have been sent to the Forest Departments of Tanganyika, Northern Rhodesia and Southern Rhodesia. The logs concerned were received in 1949 from the Urambo (Tabora) area of North West Tanganyika. Full seasoning and mycological tests have been completed on all three. Tests of strength, woodworking, impregnation with preservatives and natural durability have been begun. *Brachystegia* and *Isoberlinia*, together with *Pterocarpus angolensis* (muninga) account for over 60 per cent of the trees in the area and are very common over great areas of Central and East Africa.

At the close of the year, the following timbers had been selected for general testing. All of them were on order or about to be ordered.

Khaya ivorensis (African mahogany)	Nigeria.
Sterculia rhinopetala (brown sterculia) ..	Nigeria.
Brachystegia sp. (okwen) .. .. .. (from rain forest as opposed to savannah)	Nigeria.
Canarium schweinfurthii (canarium)	Nigeria.
Afrormosia sp. (kokrodua)	Gold Coast.
Swartzia calycina (wamara)	British Guiana.
Protium decandrum (kurokai)	British Guiana.
Erythrophloeum guineense (tali, mjembe) ..	Tanganyika.
Tectona grandis (teak) .. .. (for seasoning and woodworking tests to follow up strength tests already done)	Trinidad.

The Trinidad teak is from plantations made by the Forest Department

during the last 20 or 30 years with seed from Burma. They are highly promising in timber quality and value.

In all, the number of timbers under test, awaiting test or ordered for testing in 1950 was 48, made up as follows:

West Africa	25 species
East Africa	13 species
Caribbean area	10 species
Malay	2 species
Chile	3 species

In addition to these timbers for general testing, including qualitative peeling tests, certain supplies were obtained for individual sections for special tests. They included scented guarea for bending, peeler species for quantitative tests, tropical matchwood timbers in lieu of imported aspen, timbers for special seasoning runs, etc.

Research on Pruning

The examination of the healed-over knots in pruned trees of Sitka and Norway spruce supplied by the Forestry Commission in 1944 is virtually complete. During the year about 350 knots were analysed in full detail, and 1,200 knots by a shortened procedure likely to give all the essential information. These came from 22 Sitka and 16 Norway spruce trees taken from 17 different areas of England, Scotland and Wales. The data collected have not been analysed fully yet but appear to agree with the results of previous work. The indications are that pruning of spruce should be confined to dead branches and should be done at as small a main stem diameter as possible; and that main stem diameter is more important than refinements in close cutting of the side branches, provided the pruning is reasonably neat and close to the main stem.

Further work on this subject should be less laborious and more profitable using the simplified technique developed this year. It will involve co-operative work with the Forestry Commission on the main stem diameter at which spruce side branches usually die, and with timber merchants and consumers as to the increased value of knot-free wood from pruned stems, in spruce and other species. It is possible that pruning spruce will pay only in certain qualities and areas, and for certain markets, such as peeler logs. In pines, perhaps, and certainly in Douglas fir, the benefits from profitable pruning are greater, because they are less susceptible to fungal attack and can be pruned green with less risk, and because, in Douglas fir particularly, the branches are apt to be coarse and very persistent. The selection of races with light side branches and a tendency to prune naturally may affect the case for artificial pruning, though it is unlikely to abolish it completely.

Timber Quality in Relation to Silviculture

The study of pruning leads naturally to the study of other silvicultural factors affecting timber quality, such as rate of growth, locality, race, etc., and a programme has been arranged with the Forestry Commission. Japanese larch has been selected for a trial project. The Forestry Commission has begun a search for 20 suitable plantation trees, with a known history, on a representative site. These will be sent to the Laboratory for examination as to wood density, knots, working properties, seasoning, strength, etc., and 5 similar trees from the same crop will go to each of two well-known private

firms for sawing up, commercial grading and pricing. Some mature or semi-mature trees of Japanese and European larch from the nearest comparable sites will be handled similarly, as a basis of comparison (allowing for their different age) for the younger plantation trees, which are unlikely to be more than 12 to 18 years old yet. It is necessary to try to assess or forecast the timber quality of Japanese larch, Sitka spruce, etc., as soon as possible, though most of the trees are still too small for normal or ideal sampling, because the vigorous growth of these species or their toleration of difficult sites makes them very attractive silviculturally, even if their timber is likely to be serviceable for general purposes rather than for exacting uses.

Industrial Surveys

It has been possible this year to extend the scope of visits, and some progress has been made towards a survey of certain industries, particularly those of furniture and vehicles. The visits to merchants and consumers threw some light on the current demand for tropical woods for these industries. It is difficult to estimate the future for some of the tropical woods in the present uncertainty as to future supplies of alternatives from North America, Japan, Russia, etc. The current schemes for milling, seasoning and grading tropical hardwoods in the producing territories may, however, alter the attitude of industry in the United Kingdom towards the tropical woods; and price will as always be a very potent factor, if there is a choice.

Two officers attended the annual meeting at Oban of the Society of Foresters of Great Britain. This made it possible to discuss with State and private foresters, saw-millers and timber merchants the very fast-growing spruce and other forests of the western seaboard. A member subsequently sent to the Laboratory interesting samples of house floorboards. One is of imported Russian Norway spruce from a tree which took, perhaps, 100 years to grow. The other is of Sitka spruce grown at Inverliever, Argyll in about 30 years. Both have proved serviceable in actual housing schemes, though the fast-grown Sitka required more thorough drying and slower machining than the slow-grown Russian wood. The economic advantages of the shorter rotation are such as to outweigh much else, provided the faster-grown wood is serviceable for ordinary purposes such as housing, as opposed to exacting purposes such as aircraft and ladders.

Instruction

The customary courses in utilization have been held. The usual 5-day course was given to 31 senior forestry students of the Imperial Forestry Institute, Oxford, 17 of whom were graduates on leave from the Colonies. Other regular courses included those to forestry students of the Universities of Wales and Aberdeen, Colonial Public Works officials, and Timber Development Association instructors in timber technology. A short course was arranged for officials from the Ministry of Works Design and Inspection staff.

The Section of Seasoning has held seven courses of instruction for kiln operators during the year, and these were attended by 65 trainees.

The policy of training Colonial utilization officers has been continued, and two specially recruited utilization assistants for the Forest Departments of Tanganyika and Sierra Leone respectively were given preliminary study facilities for 3 months before going abroad to their posts. The Gold Coast Forest

Department's Utilization Officer designate spent the latter half of the year at the Laboratory. As the corresponding officers in the Forest Departments of Tanganyika, Uganda and Kenya have had similar courses of study here in previous years, very useful contact with the services of most of the major tropical timber areas of the British Commonwealth has been made, with great mutual advantage.

Visitors

On 5th September the Laboratory was honoured by a visit of H.H. the Oba of Benin, who made a tour of the various sections. It is gratifying to record that a few days later His Highness paid a second visit, unscheduled and informal, to amplify and extend his first impressions of the work.

Applications to visit have been more numerous than ever, and they pose the problem of deciding how far the interference with other work is justified by the contacts made and the information spread.

In addition to the many individual visitors with specific problems, who are never refused, numerous parties of visitors were selected for day or part-day visits. They included Colonial architects and engineers, technical college students, building managers, handicraft teachers, farmers, woodworking trade union officials and a very wide range of those concerned in one way or another with wood. A considerable number of the individual visitors was from overseas.

Lectures

In addition to the lectures given in various parts of the country on the Laboratory's general work, two series have been given, in which specific aspects have been particularly emphasized—seasoning and timber protection.

Following his tour of the U.S.A. in 1949, the Officer in Charge of Seasoning Section delivered a series of lectures in various parts of the country, under the auspices of the Kiln Owners' Association, on kiln-seasoning with particular reference to American practice; and during the year about 20 lectures have been given all over the country on insect and fungal damage and their remedy. One sound and one television broadcast have been given on the subject of wood-boring insects.

Exhibitions

Following the success in 1949 of a small exhibition on dry rot in London, Glasgow, and Belfast, it was decided to prepare, in co-operation with the Central Office of Information, a more comprehensive and elaborate exhibition on the recognition and treatment of dry rot and woodworm. Script, drawings, and material were provided for the designers and the exhibition was first shown at the beginning of May in Bristol. A senior officer from the Mycology or the Entomology Sections has attended and spoken at the opening ceremonies in most of the following cities which the exhibition has visited in 1950: Bristol, Plymouth, Swansea, Birmingham, Coventry, Preston, Manchester, Newcastle, Kilmarnock, Dundee, Edinburgh, Carlisle, Sheffield, Bradford, Liverpool and Hull. The exhibition has been well attended and in several cities between 3,000 and 4,000 people visited it during the seven days it was open in each place.

Since the prevention of dry rot depends as much on the co-operation of the occupier of a house as it does on the builder, it is important that the ordinary

householder should realize the necessity of keeping down-pipes in good condition and of maintaining ventilation under the floors, and this exhibition should have done much to educate the general public in avoiding trouble. A particular effort has also been made in each city to get into touch with teachers of building and architecture in the areas visited so that they will bring these problems to the notice of their students during their training.

Advisory and Liaison Work, External Relations

A total of 223 technical enquiries was answered by the Section in 1950. In addition to technical enquiries, the Section dealt with the usual large number of routine questions, by telephone and letter, on visits to the Laboratory, programmes of visits, the arrangement of courses, and other matters touching the external relations of the Laboratory.

F. Y. HENDERSON,
Director

FOREST PRODUCTS RESEARCH LABORATORY,
Princes Risborough,
Aylesbury, Bucks.

APPENDIX I

STAFF AT THE FOREST PRODUCTS RESEARCH LABORATORY
31*st December*, 1950

Director of Forest Products Research: F. Y. Henderson, D.Sc., D.I.C.

ADMINISTRATION

Assistant Director: S. T. C. Stillwell, O.B.E., B.Sc.
Senior Principal Scientific Officers: J. Bryan, M.Eng., A.M.Inst.C.E.; K. St.G. Cartwright, M.A., D.I.C., F.L.S.
Higher Executive Officer: R. D. Weeks.
Executive Officer: Miss D. Lacey.

SECTION OF WOOD STRUCTURE

Principle Scientific Officers: B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge); E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Scientific Officer: J. D. Brazier, B.Sc.
Experimental Officer: G. L. Franklin.
Assistant Experimental Officer: Mrs. L. F. P. Bletchly, B.Sc.
Temporary Assistant Experimental Officer: Miss L. M. Badger.

SECTION OF PHYSICS

Principal Scientific Officer: R. F. S. Hearmon, A.Inst.P. (Officer in Charge).
Experimental Officer: J. McC. Paton.
Assistant Experimental Officer: J. N. Burcham.

SECTION OF SEASONING

Principal Scientific Officer: W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officers: R. E. Hodge, A.I.Mech.E.; D. D. Johnston; G. H. Pratt; N. Turner.
Experimental Officer: A. R. Dean.
Temporary Assistant Experimental Officer: T. R. Suckling.

SECTION OF TIMBER MECHANICS

Senior Principal Scientific Officer: J. Bryan, M.Eng., A.M.Inst.C.E. (Officer in Charge).
Principal Scientific Officers: F. H. Armstrong, M.Sc., A.M.I.Mech.E.; J. Latham, B.Sc.
Scientific Officer: A. J. Comben, B.Sc.
Senior Experimental Officer: A. J. Foord.
Assistant Experimental Officers: G. R. Brock; W. T. Currey; J. G. Sunley, B.Sc.

SECTION OF WOOD PRESERVATION

Principal Scientific Officer: N. A. Richardson, B.Sc., A.R.I.C. (Officer in Charge).
Senior Experimental Officer: D. N. Smith.
Experimental Officer: L. W. Redding.
Assistant Experimental Officers: R. Cockcroft; Miss E. Lee; D. F. Purslow.

SECTION OF CHEMISTRY

Senior Principal Scientific Officer: W. G. Campbell, B.Sc., M.S., A.R.I.C. (Officer in Charge).
Senior Scientific Officer: R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C.
Temporary Scientific Officer: Miss W. R. Dutton, B.Sc.
Experimental Officer: D. F. Packman.
Temporary Assistant Experimental Officers: I. R. C. McDonald, M.Sc., A.N.Z.I.C.; L. C. Pinion, B.Sc.

SECTION OF MYCOLOGY

Principal Scientific Officer: W. P. K. Findlay, D.Sc., A.R.C.S., D.I.C., A.I.C.T.A. (Officer in Charge).
Senior Scientific Officer: J. G. Savory, B.Sc.
Experimental Officer: E. C. Badcock.

SECTION OF ENTOMOLOGY

Principal Scientific Officer: R. C. Fisher, B.Sc., Ph.D. (Officer in Charge).
Senior Scientific Officer: J. D. Bletchly, B.A., B.Sc.
Temporary Scientific Officer: M. G. White, B.A.
Senior Experimental Officer: E. C. Harris.
Assistant Experimental Officer: Miss J. M. Taylor, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer: P. Harris, B.Sc., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officer: R. Goodchild.
Experimental Officer: H. J. Endersby.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officer: C. W. Scott, O.B.E., D.F.C., B.Sc., Dip.For. (Officer in Charge).
Temporary Senior Experimental Officer: W. D. MacGregor, C.B.E., B.Sc.
Assistant Experimental Officers: Miss M. E. Smart, B.Sc.; Miss C. Webster.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer: R. A. G. Knight, B.Sc.(Eng.), M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: P. M. C. Lacey, B.Sc., D.I.C., A.C.G.I.
Scientific Officer: J. F. S. Carruthers, B.Sc.
Senior Experimental Officers: L. S. Doman; R. J. Newall.
Assistant Experimental Officer: H. A. Howe.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer: C. J. N. McCracken, B.A., Dip.For. (Officer in Charge).
Experimental Officer: C. L. Stocker, B.A., Dip.For.
Assistant Experimental Officer: Miss E. M. M. Wood.

DRAWING OFFICE AND PHOTOGRAPHY

Senior Photographer: W. J. Baldwin.
Experimental Officer: E. A. Steel.

APPENDIX II

List of Publications Issued During 1950

A. Stationery Office Publications

Forest Products Research 1939–1947.
Forest Products Research 1948.
Handbook of Empire Timbers. (Reprinted with minor amendments, 1950.)
Special Report No. 6: Swelling Stresses in Gels. By W. W. Barkas. (Revised, 1950.)

For prices see page iii of cover

B. Other Publications

*Leaflets**:

Supplements Nos. 1 and 2 to No. 44. The Seasoning of Exotic Timbers.
No. 46. Marine Borers and Methods of Preserving Timber against their Attack.

Papers published in the Scientific and Technical Press:

Armstrong, F. H. Timber as a Flooring Material—its Relative Resistance to Wear. (Paper presented to the Roads and Building Materials Group of the Society of Chemical Industry, Jan. 1950.) *Chem. Ind., Lond.*, 1950, **53,** S854–S858.

Campbell, W. G., and Packman, D. F. The Use of Timber in the Chemical Industry. (Paper presented to the Conference on "Materials of Construction in the Chemical Industry" organized by the Society of Chemical Industry, Session II. 1950.)

Cartwright, K. St.G. A Note on the Occurrence of *Trametes hispida* in England, and its Cultural Characteristics. *Trans. Brit. mycol. Soc.*, 1950, **33,** 332–334.

Farmer, R. H., and Campbell, W. G. Isolation of a Saponin from the Heartwood of the Mora Tree and of a Related Species Morabukea. *Nature*, 1950, **165** (4189), 237.

Findlay, W. P. K. Trees and Timber Fungi. *Trans. Brit. mycol. Soc.*, 1950. (*In the press.*)

A Note on the Fungi of Less Common Occurrence in Houses. *Trans. Brit. mycol. Soc.*, 1950, **34,** 35–37.

The Development of *Armillaria mellea* Rhizomorphs in a Water Tunnel. *Trans. Brit. mycol. Soc.*, 1950. (*In the press.*)

Resistance of Wood-rotting Fungi to Desiccation. *Forestry*, 1950, **23**(2), 112–115.

Henderson, F. Y., and Macdonald, J. A Survey of Research in Forestry and Forest Products in the United Kingdom. *Unasylva*, 1950, **4** (1), 14–21.

Knight, R. A. G. Address delivered to Plywood Luncheon Club at Bishopsgate, London, on Work of the Forest Products Laboratory. *Timb. Tr. J.*, 1950, **193** (3843), 912.

Exterior Plywood, being an address delivered at Annual gathering of British Plywood Manufacturers, 1950, in London. *Timb. Plywood*, 1950, **98** (2534), 176 180, 184 and 186; also *Timb. Tr. J.*, 1950, **192** (3830), 747–750.

MacGregor, W. D. Termites, Soil and Vegetation. *For. Abs.*, 1950, **12** (1), 3–7.

Stevens, W. C. Lecture on U.S. Seasoning Equipment and Technique, Held under the Joint Auspices of the Kiln Owners' Association and the Timber Development Association at Glasgow on April 27, 1950. *Timb. Plywood*, 1950, **98** (2547), 706, 708, 710 and 714; also *Timb. Tr. J.*, 1950, **193** (3843), 895–898.

Timber Seasoning with Some Reference to American Practice. (Slightly condensed from lecture given before Kiln Owners' Association.) *Timb. News*, 1950, **58** (2134), 334–335; **58** (2135), 360, 363.

The Movement of Timber. *Wood*, 1950, **15** (8), 282.

Stevens, W. C., and Turner, N. The Steam Bending Properties of Certain Timbers. *Wood*, 1950, **15** (3), 79–84.

Laminated Hoops and other Continuous Bends. *Wood*, 1950, **15** (8), 279–281.

F.P.R.L. Notes from Princes Risborough. *Emp. For. Rev.*, 1950, **29** (3), 198–199.

* Obtainable gratis from the Laboratory (Princes Risborough, Aylesbury, Bucks).

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